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INTERNATIONAL APPLICATION NO.  
PCT/JP98/01431INTERNATIONAL FILING DATE  
MARCH 30, 1998PRIORITY DATE CLAIMED  
MARCH 31, 1997TITLE OF INVENTION A MODEM DEVICE USING A CAPCITIVE INSULATING BARRIER,  
INSULATING INTEGRATED CIRCUIT USED IN THE MODEM DEVICEAPPLICANT(S) FOR DO/EO/US Yasuyuki KOJIMA, Takayuki OUCHI, Noboru AKIYAMA, Masahiro  
IWAMURA, Atsuo WATANABE, Minehiro NEMOTO, Seigou YUKUTAKE, Nobuyasu KANEKAWA

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
  - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☒ has been transmitted by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
  - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☐ have been transmitted by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendemnts has NOT expired.
  - d. ☐ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☐ A FIRST preliminary amendment.  
☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☐ A substitute specification.
15. ☒ A change of power of attorney and/or address letter.

Other items or information:

International Publication NO. W098/44687 - cover sheet  
International Search Report  
PCT Request FormFigs. 1, 2a-2b, 3-4, 5a-5b, 6a-6b, 7, 8a-8b, 9a-9c, 10, 11a-11f, 12, 13a-13b,  
14, 15a-15c, 16-17, 18a-18b, 19a-19b

17. ☒ The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5)):

Search Report has been prepared by the EPO or JPO ..... \$ 840.00

International preliminary examination fee paid to USPTO (37 CFR 1.482)  
..... \$ 670.00No international preliminary examination fee paid to USPTO (37 CFR 1.482)  
but international search fee paid to USPTO (37 CFR 1.445(a)(2)) ..... \$ 490.00Neither international preliminary examination fee (37 CFR 1.482) nor  
international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... \$ 700.00International preliminary examination fee paid to USPTO (37 CFR 1.482)  
and all claims satisfied provisions of PCT Article 33(2)-(4) ..... \$ 96.00

ENTER APPROPRIATE BASIC FEE AMOUNT =

\$ 840.00

Surcharge of \$130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30  
months from the earliest claimed priority date (37 CFR 1.492(e)).

\$

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE
Total claims	52 - 20 =	32	X\$18.00
Independent claims	20 - 3 =	17	X\$78.00

\$ 576.00

\$ 1326.00

MULTIPLE DEPENDENT CLAIM(S) (if applicable)

+ \$260.00

\$ 260.00

TOTAL OF ABOVE CALCULATIONS =

\$ 3,002.00

Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement  
must also be filed (Note 37 CFR 1.9, 1.27, 1.28).

\$

SUBTOTAL =

\$ 3,002.00

Processing fee of \$130.00 for furnishing the English translation later than ☐ 20 ☐ 30  
months from the earliest claimed priority date (37 CFR 1.492(f)).

\$

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TOTAL NATIONAL FEE =

\$ 3,002.00

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be  
accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property

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a. ☒ A check in the amount of \$ 3,002.00 to cover the above fees is enclosed.b. ☐ Please charge my Deposit Account No. \_\_\_\_\_ in the amount of \$ \_\_\_\_\_ to cover the above fees.  
A duplicate copy of this sheet is enclosed.c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any  
overpayment to Deposit Account No. 01-2135. A duplicate copy of this sheet is enclosed.NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR  
1.137(a) or (b)) must be filed and granted to restore the application to pending status.

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## SPECIFICATION

A MODEM DEVICE USING A CAPACITIVE INSULATING  
BARRIER, AN INSULATING COUPLER, AND AN INTEGRATED  
CIRCUIT USED IN THE MODEM DEVICE

## 5 FIELD OF THE INVENTION

The present invention relates to a modem device  
and system using a semiconductor device, a capacitor  
formed on the semiconductor device, particularly an  
insulating barrier which is a highly dielectric  
10 capacitor which will not break the device even if a  
high voltage is applied and will not supply a  
dangerous voltage to the secondary side, an insulating  
coupler, or an isolator, or an insulating amplifier  
transferring an electric signal using the insulating  
15 barrier (hereinafter referred to as an insulating  
coupler), an application circuit using the insulating  
coupler, particularly a line interface circuit for the  
modem device and others, and an IC thereof.

## PRIOR ART

20 To protect extremely public network facilities and  
protect terminals, the communication field requires a  
high insulation quality for boundaries (hereinafter  
referred to as line interfaces) between networks and  
terminals and miniature communication transformers  
25 having a high insulation quality have been used.

However, as personal terminals have come into wide use and expanded recently, more miniature and light terminals are required as portable terminals, and a problem arises that the need for miniaturization is not sufficiently filled by improvement of the material and structure to be used for a transformer, and an application of the insulating coupler has been examined.

In uses such as measurement and medical treatment, there is a case that it is necessary to insulate between the signal detection unit and the signal processing unit such as a sensor and a signal processing circuit and the insulating coupler is known as an insulation separation means in such a case.

In such a case, although the signal voltage is about 100 mV, since a case that the commercial power supply comes in contact is assumed, there is a case that 100 V or a higher voltage is applied as a common mode noise voltage. In these respects, the insulating coupler and line interface have a common problem from the viewpoint of high dielectric strength, miniaturization, and low cost.

The insulating coupler is also the function itself of an insulating transformer, though there is a problem imposed that noise is mixed during transfer of



a signal. For example, when a large common mode noise voltage is applied from the commercial power supply, a small signal transmission transformer may not transmit a signal and a transformer type insulating coupler using a dedicated pulse transformer is used. The insulating coupler using an insulating transformer is generally large in the mounting configuration and apt to be expensive.

To improve it, an insulation amplifier using a photo coupler combining a light emitting device and a photo detector has been designed. However, the photo coupler type insulation amplifier easily changes the characteristics due to temperature and to make it highly precise, improvements of the number and arrangement of light emission and detection diodes and circuits have been proposed but they are expensive. Users request further miniaturization. However, if it is attempted to particularly realize a monolithic semiconductor, a semiconductor process of another material for light emission and detection is required in addition to the silicon semiconductor process, and by use of several kinds of manufacture processes, it is expected that such a monolithic semiconductor will be remarkably expensive, and it cannot be practically realized.

For the purpose of miniaturization, high reliability, and low cost, capacitive insulating couplers have been developed. As a highly dielectric capacitor art as an individual part constituting an insulating barrier, a ceramic capacitor for power or surge protection is known and a circuit block for signal transmission using it is called a capacitive insulating amplifier or capacitive insulating coupler and has been used since 1970s.

As a transmission system for transmitting a signal via a capacitive insulating barrier, the PWM system (called the pulse width modulation system or duty control system) is mainly used. This PWM art is known as a constitution art of an insulating barrier using an insulating transformer or photo coupler before it is used for this capacitive insulating coupler.

In the capacitive insulating coupler, furthermore, for the purpose of miniaturization, low cost, and high reliability, an insulating amplifier of a duty cycle modulation system is proposed using an insulating barrier which is a capacitor with a small capacity formed on a ceramic substrate and a floating comparator. For further miniaturization, a proposal of reducing the capacity is made and an art of an insulating amplifier for changing a transfer waveform

to a differential waveform using a small insulating barrier such as about 1 to 3 pF, reproducing an FM (frequency modulation) or PWM waveform from the differential waveform, and then demodulating is  
5 proposed.

With respect to application of a line interface of a modem and others, in USP 4757528, "Thermally coupled Information transmission across electrical Isolation boundaries" (hereinafter referred to as Patent 528)  
10 and ISSCC86 conference record THPM14.3 (hereinafter referred to as Announcement), Scott L. Falater (Harris Semiconductor) et al. disclose an idea of realization of a monolithic semiconductor using a capacitive insulating barrier.

15 Although it is not monolithic, three capacitive insulating barriers and a modem application circuit system of digital PWM signal transmission using them are proposed in Japanese Patent Application Laid-Open 7-307708.

20 For these circuits, a request of further miniaturization and lower cost will be presented in the future and when these prior arts are examined from this point of view, the following subjects and problems arise.

25 According to the art before Patent 528, an

insulating barrier having highly dielectric performance, an input circuit receiving an input signal and generating a PWM waveform, and an output circuit reproducing and demodulating a PWM waveform  
5 are different parts and these parts are assembled and mounted so as to constitute one insulating coupler. For example, a capacitive insulating barrier is structured on a ceramic substrate and at least two semiconductor chips are mounted on the same package so  
10 as to constitute an insulating coupler. Namely, a constitution using many parts is provided.

In Patent 529 and Announcement, it is indicated that as an idea that a line interface which is an application circuit comprises a monolithic  
15 semiconductor, a capacitive insulating barrier and the PWM transmission system are used by the circuit schematic diagram which is a principle and explanation. The manufacturing method is that an insulating coupler comprising a capacitive insulating barrier using the  
20 DI (dielectric separation) process and a PWM circuit is formed on a monolithic semiconductor and a sound band signal is transmitted by combining this insulating coupler. However, the disclosed art is an art regarding control of an insulating switch by a  
25 thermal pulse and it is not disclosed that an

insulating barrier and circuit of what a kind of  
structure are structured on a monolithic semiconductor  
substrate by what a kind of method and as a result,  
how the structure operates and what an affect the  
5 structure produces.

Furthermore, in Japanese Patent Application Laid-  
Open 7-307708, although two insulating barriers are  
conventionally used for one transmission path, a  
circuit constitution for transmitting three signals by  
10 three capacitive insulating barriers is indicated but  
how the circuits operate so as to transmit signals is  
not indicated. Needless to say, a proposal for making  
these circuits including the insulating barriers  
monolithic is not made.

15 Users request to make the modem circuit and  
insulating barriers smaller and cheaper and for that  
purpose, it is considered to be essential to realize a  
monolithic semiconductor. However, the aforementioned  
prior arts do not disclose arts on how capacitive  
20 insulating barriers, circuits for using capacitive  
insulating barriers, arrangement of them, and an  
insulating method between arranged circuits are  
structured on a semiconductor substrate and how they  
are operated so as to realize a monolithic IC  
25 insulating coupler, a monolithic IC application

circuit, and a monolithic IC line interface circuit.  
Therefore, how the dielectric strength is realized so  
as to produce a monolithic IC and characteristics of  
the highly dielectric capacity formed on the  
5 semiconductor are not known at all.

When a plurality of insulating couplers are  
simultaneously operated in parallel, noise is  
generally generated stationarily by the operation of a  
certain insulating coupler, and crosstalk is generated  
10 in the other insulating couplers by the generated  
noise, and the transmission characteristic of the  
insulating couplers is affected, and the S/N of a  
signal to be transmitted via the insulating barriers  
is degraded by it. Particularly, when the signal level  
15 is low like model application and the amplitude of a  
signal is greatly different between rising and falling,  
even small crosstalk comes into question. However,  
there are no prior arts responding to these problems.

#### DISCLOSURE OF THE INVENTION

20 An object of the present invention is to realize a  
compact and economical line interface circuit having a  
built-in insulating means necessary between a line and  
a terminal and a modem device and to realize a  
monolithic insulating barrier necessary for it, a  
25 monolithic insulating coupler using the insulating

barrier, an application circuit IC using it, and particularly a line interface circuit IC.

Another object of the present invention is to provide an art for structuring a capacitive insulating barrier on a semiconductor substrate.

Still another object of the present invention is to provide an art for structuring an insulating coupler using a capacitive insulating barrier on a semiconductor substrate.

10 A further object of the present invention is to provide a structure, arrangement, and operation method of an application circuit using a plurality of insulating couplers on a semiconductor substrate, particularly a line interface and furthermore to  
15 provide an art for reducing degradation of a signal due to a timing hazard and crosstalk such as a timing synchronization method between the insulating couplers.

A still further object of the present invention is to realize a low leakage current when a line is not  
20 used for communication in a line interface comprising an insulating coupler.

A still further object of the present invention is to provide a breakdown dielectric strength improvement art for a surge voltage of an insulating coupler.

25 A still further object of the present invention is

to make a modem device and a system smaller and more economical using an insulating coupler.

The present invention uses the following means so as to solve the conventional problem of a large size  
5 and a high price.

(1) On the surface of a semiconductor wafer (SOI wafer) having a buried insulating layer as an inner layer, an insulating band reaching the insulating layer (hereinafter referred to as an insulating band)  
10 is formed and an insulating barrier is formed between the side walls of the insulating band.

(2) A plurality of circuit areas enclosed by an insulating barrier and an insulating band are formed, and the circuit areas are insulated from each other,  
15 and a monolithic insulating coupler is formed.

(3) In the insulating coupler, at least amplification means for a capacitor output signal such as an amplifier and comparator are provided in the circuit receiving capacitor output.

20 (4) In the line interface circuit of a modem device and others, a plurality of monolithic insulating couplers, a line side circuit, and a terminal side circuit are provided.

(5) The configuration of IC integration is as  
25 follows:



1) a line side circuit including a highly dielectric device,

2) a terminal side circuit including the AFE (analog front end) which is a lowly dielectric device,  
5 and

3) all units are integrated.

These are supported by the monolithic insulating coupler.

(6) On the low voltage side, there is  
10 particularly a configuration that a plurality of monolithic insulating couplers are built in the AFE.

(7) The line interface circuit is structured using a monolithic AFE integrated circuit (I-AFE) and the modem circuit is realized.

15 (8) To connect and operate the modem circuit comprising a DSP (digital signal processor) and I-AFE, the DSP, I-AFE, and these insulating couplers are synchronized in timing using the operation clock of the DSP.

20 By doing this, it is possible to realize highly dielectric strength by the insulating layer and insulating barrier and to correct a reduction in the signal amplitude due to the stray capacitor by the amplification means, or reduce the degradation of a  
25 signal due to crosstalk by synchronizing the operation

timing, and realize a compact insulating coupler of high performance and a modem interface circuit.

The present invention will be explained slightly concretely hereunder.

5       According to the present invention, a semiconductor IC is formed by processing a semiconductor wafer having a buried insulating layer as an inner layer, forming an insulating barrier, an insulating coupler, an application circuit of the  
10       insulating coupler, and particularly a line interface circuit, overlapping the insulating layer and wiring layer as required, and furthermore forming a protective layer serving as insulation. Each circuit is insulated by enclosing by the insulating layer,  
15       insulating band, and insulating protective layer. The insulating band is, for example, a band-shaped insulating pattern with a width of about 1 to 3 microns reaching the insulating layer from the surface of the semiconductor layer (the thickness is equal to  
20       the thickness of the semiconductor layer, for example, 10 to 50 microns) and the insulating band is formed by the trench method for forming a groove of the predetermined pattern reaching the inner insulating layer from the surface of the semiconductor and  
25       burying it in an insulator or the ion implantation

method for implanting oxygen ions in the semiconductor layer and creating an insulating area. Hereinafter, a portion enclosed by the insulating band is referred to as an electrode area or a circuit area with "area"

5 added.

In application of the line interface of the insulating coupler of the present invention, it is necessary to build in a plurality of insulating couplers. In this case, to connect a monolithic line  
10 interface IC in which a plurality of capacitive insulating couplers, a line side circuit, and a terminal side circuit are provided to a modem circuit comprising a DSP and an AFE and operate it, the timing is synchronized between the DSP, AFE, and the  
15 operation clock of these insulating couplers. The carrier clock of the insulating coupler for receiving a modem signal is reproduced and used from the clock of the DC loop control signal transfer coupler. The DC loop control drives the CMOS switch by the charge pump  
20 circuit using the insulating barrier and loops the direct current.

The insulating barrier in the insulating coupler of the present invention structures a capacitor by forming electrode areas by enclosing by the insulating  
25 band and arranging so that a plurality of electrode

areas share a part of the insulating band or so that the common length is sufficiently long to obtain a necessary capacity. By setting the shape and arrangement of the insulating band so that three or  
5 more electrode areas share two or more insulating areas, that is, by the multi-trench, it is possible to form capacitors connected in series. The buried insulating layer has a thickness such that the insulating performance corresponding to the width of  
10 the insulating band is provided.

The insulating coupler of the present invention is realized by forming the insulating barrier, input circuit, and output circuit on the same wafer. Each circuit is enclosed by an insulating band and  
15 insulated from the other parts. The insulating barrier is arranged on the boundary between the input circuit area and the output circuit area in principle. These circuit areas and the insulating barrier are ganged together and further enclosed by an insulating band.  
20 In the input circuit and output circuit, a PWM modulator and PWM demodulator or another circuit depending on the purpose, for example, a circuit digitized not only in the amplitude direction but also in the time base direction such as a  $\Sigma\Delta$  modulator and  
25 demodulator for a signal in the voice frequency band

are included respectively. Between the insulating barrier, input circuit, and output circuit, a protective circuit comprising a non-linear device such as a diode is arranged respectively. The protective  
5 circuit is arranged within the circuit area.

The application circuit of the present invention is realized by further arranging an application circuit area enclosed by an insulating band in the insulating coupler. When a plurality of said  
10 insulating couplers are included, the insulating barrier may be arranged along the insulating barrier arrangement line. To operate a plurality of insulating couplers, the transfer block is synchronized as required. In application of the insulating couplers to  
15 the line interface circuit, it is particularly possible to further divide the CMOS circuit area into the PMOS group to be connected to the power cable and the NMOS group to be connected to the grounding cable and separate them by an insulating band so that the  
20 CMOS circuit is included in the circuit area. The power cables are laid out between a plurality of insulating couplers. The neighborhood of each insulating coupler may be enclosed by a power cable and grounding cable. For example, with respect to the  
25 CMOS circuit, there is an advantage that voltage

control requiring no control current and a high off-state resistance are obtained. On the other hand, a through phenomenon of the PMOS and NMOS including the parasitic transistor, that is, latch-up is easily  
5 generated. However, there is an advantage that by separating the area as mentioned above, such a phenomenon is hardly generated.

Highly dielectric strength in the thickness direction is realized by use of an insulating inner  
10 layer wafer, and a very miniature insulating barrier is realized by forming two electrode areas having a shared insulating band on the same wafer, and a very miniature insulating coupler can be realized by forming the insulating barrier and two circuit areas  
15 of an input circuit and an output circuit on the same wafer. Furthermore, by overlapping electrode areas, connecting the capacities in series, and realizing highly dielectric strength in the horizontal direction, more highly dielectric strength can be realized even  
20 if the width of one insulating band cannot be spread due to restrictions on the process. Furthermore, by floating the intermediate electrode during arrangement of the series capacities, extended cables in the strongly energized electric field can be reduced.

25 In the case of application using a plurality of

insulating couplers, by arranging the capacitive insulating barriers such as electrodes and insulating bands, the insulating performance can be homogenized.

In the case of application of the line interface, by synchronizing the transfer clocks of a plurality of insulating couplers, the PWM crosstalk to a transmission signal can be minimized. By using the CMOS circuit system as a circuit system, the DC loop control circuit which is a line connection switch can be controlled in voltage using the charge pump. The CMOS circuit system realizes high impedance of the switch when it is off and realizes a low leakage current. By installing a protective circuit at each terminal of the insulating barriers in the same way as with an external connection terminal, destruction of the device due to surge noise can be prevented.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a circuit block diagram of a modem device of the first embodiment of the present invention.

Fig. 2 is an operation timing chart of the modem device shown in Fig. 1.

Fig. 3 is a circuit block diagram of the insulating coupler shown in Fig. 1.

Fig. 4 is an operation timing chart of the

insulating coupler shown in Fig. 3.

Fig. 5 shows synchronization of a modem signal process and an insulating coupler timing chart.

Fig. 6 is a timing chart showing an effect of  
5 timing synchronization.

Fig. 7 is a layout of the IC of the line interface circuit in the circuit shown in Fig. 1.

Fig. 8 is a structural diagram of the insulating coupler in the IC shown in Fig. 7.

10 Fig. 9 is a structural diagram of the insulating barrier in the IC shown in Fig. 7.

Fig. 10 is a deformation example of a layout of a line interface IC.

Fig. 11 is a circuit block diagram of the  
15 insulating coupler system applied to the present invention.

Fig. 12 is a circuit block diagram of a modem device of another embodiment of the present invention.

Fig. 13 is a timing chart showing an effect of  
20 another embodiment of a modem.

Fig. 14 is a structural diagram of another embodiment of an IC of a line interface circuit.

Fig. 15 is a structural diagram of another embodiment of the insulating barrier of the present  
25 invention.



Fig. 16 is a structural diagram of an embodiment of the insulting coupler of the present invention.

Fig. 17 is a structural diagram of another embodiment of the insulting coupler of the present invention.

Fig. 18 is a structural diagram of still another embodiment of the insulting coupler of the present invention.

Fig. 19 is a structural diagram of a modem device using the line interface IC of the present invention.

Fig. 20 is a circuit block diagram of an embodiment of a line interface circuit containing the monolithic insulating coupler of the present invention.

Fig. 21 is a layout conception diagram of the IC (I-AFE) of the line interface circuit shown in Fig. 20.

Fig. 22 is an embodiment of a modem circuit using the IC (I-AFE) shown in Fig. 21.

Fig. 23 is an embodiment of a modem device using the IC (I-AFE) shown in Fig. 21.

Fig. 24 is an embodiment of another communication device using the monolithic insulating coupler of the present invention.

Fig. 25 is an embodiment of another layout of the monolithic insulating coupler of the present invention.

Fig. 26 is a circuit block diagram of another

embodiment of the monolithic insulating coupler of the present invention.

Fig. 27 is a detailed circuit diagram of Fig. 26.

Fig. 28 is an operation timing chart of the  
5 detailed circuit diagram of Fig. 27.

Fig. 29 is a circuit block diagram of an embodiment that a plurality of insulating couplers are loaded on the same SOI substrate.

#### DESCRIPTION OF PREFERRED EMBODIMENTS

10 The present invention will be explained hereunder according to the embodiments.

The modem device of the first embodiment of the present invention will be explained with reference to Figs. 1 to 9.

15 Fig. 1 is a circuit block diagram of the modem device of the first embodiment of the present invention. In Fig. 1, numeral 1 indicates a modem and 2 indicates a line interface circuit. The modem circuit 1 comprises a DSP (digital signal processor: a  
20 dedicated processor for processing a digital signal) 3 and an AFE (analog front end) 4 and the line interface circuit 2 comprises a terminal side circuit 5, an insulating coupler 6, a circuit side circuit 7, and a high voltage circuit 8. The roles of the DSP 3 and the  
25 AFE 4 in the modem 1 are that the DSP 3 processes a

digital signal and the AFE 4 serves as an interface with the digital circuit and analog circuit. Namely, the DSP 3 sends or receives digital information to or from a terminal and also performs processes such as modulation, demodulation, coding, decoding, and filter processing by the digital signal processing and sends or receives a digital signal to or from the AFE 4. The AFE 4 performs AD (analog to digital) conversion, DA (digital to analog) conversion, and filtering. The line interface circuit 2 may be referred to as a DAA (direct access arrangement) and has a function for directly connecting an analog signal of the modem to the telephone line and simultaneously sending or receiving a signal such as line connection, sending of a dial signal, or detection of a terminating signal to or from the switchboard corresponding to the modem by the line side circuit 7 and the high voltage circuit 8. However, an interface function for safety between the switchboard and a terminal is necessary and the insulating coupler 6 serves as a boundary for this safety.

The DSP 3 contains a ROM (read only memory: a dedicated memory for reading) 31, a PU (processing unit: a unit for performing arithmetic) 32, a RAM (random access memory: a memory for reading and

writing) 33, a system interface 34, a SOR (serial  
output interface) 35, a SIR (serial input interface)  
36, I/O (input and output interface) 37, and CONT  
(controller in the DSP) 38 and they are connected by  
5 three buses 39-1, 39-2, and 39-3. The DSP 3 is  
controlled by the software in the DSP system control  
circuit CONT 38, operates at about 40 MHz, operates by  
an instruction from a terminal device via HOST-IF, and  
receives data. A normal modem has a concurrent  
10 communication capability of sending and receiving.  
Upon receipt from HOST-IF, sent data is stored in the  
RAM 33 once, subjected to signal conversion, coding,  
and filtering using the data in the ROM 31 and the  
already stored sending signal, and outputted via the  
15 SOR 35. After an AD signal is received from the SIR 36,  
the received signal performs various filtering  
processes, judgment, and code conversion using the  
sending signal stored in the RAM, already received  
signal, and data in the ROM 31. The I/O 37 has a  
20 control signal I/O function for controlling an  
external circuit from the DSP 3.

The AFE 4 comprises a DA converter 41, an AD  
converter 42, and a clock divider 43 and mainly serves  
as an interface means for inputting and outputting a  
25 modem signal by the DSP 3 controlling the filtering

and modulation and demodulation processes. The terminal side circuit 5 is a circuit for connecting data and the clock. The insulating coupler 6 comprises a sending path 61, a receiving path 62, an OFHK path 63, and an Rdet path 64 and details of the internal constitution and operation will be described later. The line side circuit 7 comprises a 2-wire - 4-wire conversion circuit 71, a switch control circuit 72, and an OSC (local originating circuit) 73 and the 2-wire - 4-wire conversion circuit 71 is a hybrid circuit means for suppressing 4 wires of sending signal paths and receiving paths and 2 wires on the line side so that a sending signal will not turn to the receiving side. The high voltage circuit 8 comprises a DC loop circuit 81 and a Ring (call signal) detection circuit 82 for detecting a call signal and the DC loop circuit 81 is a means for connecting to two terminals TIP and RING of line connection and generating a DC loop by the control signal OFHK path 63 and the switch control circuit 72.

The first structural characteristic of this modem circuit is that the circuits on the line side and terminal side are separated by the 4 insulating couplers 6. The power supplies are also separated rightfully and the power supply on the line side uses

power supplied from the exchange and the terminal side  
uses the power supply at the terminal. The second  
characteristic is that the basic clock is supplied  
from the DSP 3. As shown by the thick arrow lines in  
5 the drawing, the timing signal obtains the AD  
conversion timing (MCLKS) and DA conversion timing  
(MCLKR) of the AFE in the modem and the data  
transmission timing of the modem 3 from the clock  
circuit 43 using the clock signal DSPCLK supplied from  
10 the CONT 38 of the modem 3, supplies them to the line  
interface circuit 2, and gives them to the sending  
path 61 of the insulating coupler 6 and the OFHK path  
63 of the control signal sending insulating coupler.  
On the other hand, the receiving path 62 of a modem  
15 signal uses the reproduced clock of the OFHK path 63  
and the Rdet path 64 of the control signal receiving  
insulating coupler is significant only when it  
receives the RING signal in the reception standby  
state, so that oscillation is controlled by the OFHK  
20 signal. By doing this, the paths other than the Rdet  
signal path synchronize with the operation timing of  
the DSP 3 in the modem 1. By doing this, the effect  
described later can be obtained.

Next, the operation of this circuit as a modem  
25 function will be explained by referring to Fig. 2.

Fig. 2 shows an example of a timing chart which is divided into during sending (a) and during receiving (b). During sending, the DSP 3 controls the I/O 37 according to an instruction from a terminal first and turns the DC loop control signal OFHK off (T1). When the line (that is, the switchboard) responds to the DC looping (T2), the line interface circuit 2 sends a dial signal. This is executed by turning the OFHK terminal ON or OFF according to the line standard and turning the DC loop ON or OFF. For example, in Japan, it is 10 PPS (pulse per second) or 20 PPS. When the sending of the dial signal ends (T3), the terminal waits until the line is connected to the remote modem (T4), activates the modem 1, and starts sending.

According to the activation instruction, the modem 1 generates sending signals TXA+ and TXA- via the SOR 35 of the DSP 3 and the DA converter 41 of the AFE 4 according to the predetermined procedure and starts up communication with the remote modem. The line interface circuit supplies the TXA signal to the 2-wire - 4-wire conversion circuit 71 via the sending path 61 of the insulating coupler 6. The 2-wire - 4-wire conversion circuit 71 reduces turning to the receiving side and sends the sending signal to the line from the TIP and RING terminals via the DC loop

circuit 81. When the remote modem responds to this  
sending signal (T5), the signal of the remote modem  
can be seen on the line, and the receiving signal is  
selected by the 2-wire - 4-wire conversion circuit 71  
5 via the reverse path, transferred to the modem 1 via  
the receiving path 62 of the insulating coupler 6, the  
AD converter 42 of the AFE, and the SIR 36 of the DSP  
3, and amplified, filtered, and demodulated by the  
signal process of the DSP, and the digital data is  
10 restored and transferred to the host as received data.  
To stop the communication, the terminals send and  
receive their stop information by the protocol which  
is upper than that of the modem signal and then output  
a stop instruction to the respective modems (RS off)  
15 and each modem stops the signal in response to it (T6,  
T7). When this communication ends (T8), OFHK is turned  
off. By doing this, a signal roughly like the one  
"between TIP and RING" shown in Fig. 2 appears between  
the line connection terminals TIP and RING in  
20 correspondence with each timing from T1 to T8.

During receiving, the modem is activated by the  
RING signal from the line side (T1) and when the line  
interface circuit detects it by the RING detection  
circuit 82, it immediately transfers it to the modem 3  
25 via the Rdet path 64 of the insulating coupler 6. The



modem 3 becomes aware of it through the I/O circuit 37 and when the modem 3 responds to it, it outputs the DC loop control signal OFHK in the same way as with during sending and loops the DC (T2). When the DC is looped, the switchboard of the office stops the RING signal (T3), so that the remote modem sends a modem signal after waiting for the decided time of the line (T4). Therefore, the modem 3 receives it as signals RXA+ and RXA- and when the receiving side modem recognizes it as a modem signal, it responds to it and starts sending (T5). Also when the communication is to be completed, it ends by almost the same sequence as that during sending such as T6, T7, and T8. During these receiving operations, the signal shown in the drawing (schematically indicated) appears on the line in correspondence with each timing from T1 to T8. This operation itself is generally as specified in the standard.

Fig. 3 is a circuit block diagram of one path of the insulating coupler 6 in the embodiment shown in Fig. 1. In Fig. 3, numerals 9-1 and 9-2 indicate capacitive insulating barriers which will be described later, 21 an input circuit, and 22 an output circuit and a safety boundary between the terminal of the modem and the switchboard is realized by the

insulating barriers. The input circuit 21 inputs power and a signal from a terminal 103, comprises a modulation circuit 104, a drive circuit 105, and a protection circuit 106, converts and modulates an inputted analog signal, converts it to a PWM (pulse width modulation) signal, and outputs the signal to the output circuit 22 via the insulating barriers 9-1 and 9-2. The output circuit 22 comprises a protection circuit 107, a detection circuit 108, and a demodulation circuit 109, supplies power from a terminal 110, detects a signal sent from the insulating barriers 9 by the detection circuit 108, reproduces a PWM signal from the detected signal by an integration circuit 135 and a comparison circuit 137, and reproduces an analog signal corresponding to the input signal from the PWM signal. The output circuit 22 also has a function for extracting a timing signal from the detected signal and outputting these signals.

The terminal 103 on the input side includes power terminals VDD1 and VDD2, a grounding terminal VSS1, and a clock input terminal for differential input of + and - as signal input and modulation timing. The modulation circuit 104 comprises a comparison circuit 111 and a carrier generation circuit 112. The drive circuit 105 is an inverter driver comprising PMOS

transistors 113 and 114 and NMOS transistors 117 and 118. The protection circuit 106 comprises diodes 121, 122, 123, and 124 and resistors 129 and 130 and prevents circuit breakdown due to approaching of a surge voltage from the side of the output circuit 22. The protection circuit 107 on the side of the output circuit 22 comprises resistors 131 and 132 and diodes 125, 126, 127, and 128 and protects the gates of the transistors of the detection circuit 108. PMOS transistors 115 and 116 and NMOS transistors 119 and 120 constitute a detection circuit of an inverter constitution having feedback resistors 133 and 134. The output of the detection circuit 108 is connected to the integration circuit 135. The integration circuit 135 reproduces a PWM waveform from an inverter output signal. Numeral 136 indicates a circuit for reproducing the timing of a carrier and 137 indicates a comparison circuit. The terminal 110 on the output circuit side supplies power from power terminals VDD3 and VDD4 and a grounding terminal VSS2 and outputs the signal outputs + and - of a complementary type of processing results and the timing clock. The characteristics of this constitution are (1) the two insulating barriers 9-1 and 9-2 are used, and (2) an external clock is inputted, and (3) a reproduced clock

is outputted. Although not indicated because a normal I/O protection circuit is used, for the signal input + and - terminals and clock input terminal among the terminals 103 shown in this circuit block diagram, an  
5 input protection circuit is installed when they are to be independently used as an insulating coupler. In the explanation of this circuit constitution, a combination of PMOS and NMOS is indicated. However, depending on the purpose, the bipolar process or  
10 coexistence process may be used. Furthermore, for the purpose of independent use of the insulating coupler, a clock may be internally generated.

Next, the operation of the insulating coupler of this embodiment will be explained by referring to Fig.  
15 4. Fig. 4 is an operation timing chart of the insulating coupler shown in Fig. 3 and the signal transmission system is the PWM (pulse width modulation) system. A carrier sufficiently higher (1.2288 MHz, 256 times or more in this case) than the  
20 frequency band (about 3.4 kHz max. in this case) of an input signal having a waveform to be transferred is used, and the time axis is divided for each fine period  $T$ , and an input signal at each time is transmitted by converting the magnitude thereof to  
25 each pulse width  $t$ . When an input signal is at 0 V,

$t/T=0.5$ , that is, the duty is 50% and the duty is converted so that as the input signal increases positively, the pulse width increases and as the input signal increases negatively, the pulse width decreases.

5 To reduce the effect of common mode noise, an input signal is differentially inputted such as input signal + and input signal -. However, depending on the purpose, another input system may be used.

Fig. 4 schematically shows a sine wave when it is  
10 applied to the + and - input terminals. The rectangular clock inputted from outside the insulating coupler is converted to a saw tooth waveform by the carrier generation circuit 112 and used as a carrier. The modulation circuit 104 is the comparison circuit  
15 111 and outputs the PWM + and PWM - waveforms in which the pulse duty is changed by receiving these input signals. The drive circuit 105 inputs the PWM + and PWM - waveforms to the drive circuit 105 and supplies them to the one-side terminals of the insulating  
20 barriers 9-1 and 9-2 via the protection circuit 106. The capacitor values of the insulating barriers 9-1 and 9-2 are about 1 pF. The protection circuit 106 is set at a constant such that it is effective in a high voltage surge waveform of several tens ns or less, so  
25 that it will hardly affect this drive waveform. The

other electrodes of the insulating barriers 9-1 and 9-2 input to the detection circuit 108 via the protection circuit 107. This detection circuit 108 is the inverter and integration circuit 135. The inverter  
5 output has a differential waveform like those of the detection signals + and - and is extremely attenuated due to the stray capacity, so that it is amplified by the inverter once and inputted to the integration circuit 135. The integration circuit 135 is an  
10 integrator having two input terminals of + and - and inputs a signal in a differential waveform, so that it outputs reproduced PWM signals + and - as shown in the drawing. The timing reproduction circuit 136 is a PLL circuit and extracts the timing signal component from  
15 the reproduced PWM signal. When a saw tooth waveform is generated using the timing waveform and it is subjected to sample-holding at the timing of the reproduced PWM signal, a demodulated waveform like the output signals + and - can be reproduced.

20       The circuit operation of this insulating coupler is explained above. In execution of the present invention, as a PWM realization method, another method may be used. For example, the modulated waveform may be a triangular wave. When a triangular wave is used,  
25 the center timing of the modulated waveform becomes

constant, so that for example, there is an effect that a high precision timing reproduction system like PLL can be used in the demodulation circuit. In the output circuit, a flip-flop of a set-reset type may be  
5 arranged in place of the integration circuit. The startup timing of a differential waveform which is an inverter output is the PWM timing information itself and by properly selecting the characteristics of the load resistor and inverter, it can be used as a flip-  
10 flop control signal as it is. The output of the flip-flop is the PWM waveform itself.

The characteristic of this operation timing is that the three control signals of sending signal, receiving signal, and line connection control signal  
15 are transferred in parallel. As a result, in a line interface using this insulating coupler, the crosstalk of a signal becomes noise and the SN ratio is degraded. Therefore, in this embodiment, the DSP operation timing, modem processing timing, and insulating  
20 coupler timing are synchronized and this degradation is suppressed. This will be explained by referring to Fig. 5.

Figs. 5(a) and 5(b) show the relationship between the modem signal process and the insulating coupler  
25 operation timing. The characteristic of the circuit

constitution of this embodiment is that the operation timing of the line interface circuit is supplied from the modem and the circuit operation in the IC is synchronized with this clock. In Fig. 5, (a) shows the modem signal processing portion and although the timing chart is schematic, the relationship is shown on the right side of the chart. Namely, in the mode signal processing portion, the DSP operates at 39.3216 MHz, and 1.2288 MHz is supplied to the AFE and used as DA conversion timing MCLKS and AD conversion timing MCLKR. The DA conversion and AD conversion system is a 256-times over sample system, so that the substantial value is 9.6 ksps. (b) shows the clock timing relationship of the line interface portion and the clock signal DSPCLK supplied from the DSP is supplied to the sending signal path 61 of the insulating coupler 6 and the control signal path 63 as NCLKS and synchronized with the modem operation timing. It is desirable that the receiving signal path NCLKR operates only when the control signal is in the ON state, so that it has a gated waveform as shown in the drawing. Although the timing CLK2 of the Rdet path is locally generated in the line side circuit, it is stopped by the control signal OFHK during sending and receiving of a signal between the modems.



The effect obtained by synchronizing the operation timings of the DSP, AFE, and insulating coupler like this will be explained by referring to Fig. 6.

In Fig. 6, (a) shows the PWM modulation timing  
5 when the saw tooth waveform is used as a carrier. With respect to modulation, a saw tooth waveform changing to a carrier waveform by integrating a clock signal is generated and a PWM modulated waveform is obtained by comparing it with a transmitting signal. In the  
10 drawing, the receiving signal, sending signal, and OFHK control signal are shown. The receiving signal is affected by the transmission loss on the line as shown in RXA + and - in Fig. 1, so that the amplitude is small such as from -20 to -45 dBm or so. On the other  
15 hand, the sending signal is sent by itself, so that the amplitude is large, generally from -6 to -15 dBm or so. The control signal is at a logic level of 5 V, showing a maximum value. When these amplitudes are converted to PWM duty, as shown in the drawing, the  
20 signal with a small amplitude deflects in a narrow width and the signal with a large amplitude deflects in a large width. With respect to the property of the signal, the modem waveform is an AC signal, so that the deflection can be seen as shown in the drawing and  
25 the control signal is seen as if it is stopped. In

this embodiment, the timing of each insulating coupler is synchronized, so that as shown in Fig. 6, the carrier waveform, modulated waveform, and PWM waveform of the control signal are lined up and the mutual interference is minimized. In the modem circuit, a sending or receiving signal is converted from analog to digital or from digital to analog at the predetermined timing. However, even if sampling is executed for each period T in the PWM portion by synchronizing the clock supplied from the modem with it, the effect can be minimized (in the asynchronization, there is an effect of beat noise).

The principle of crosstalk reduction will be explained hereunder more in detail.

When a plurality of insulating couplers of pulse width modulation are operated at the same time, the PWM waveforms are overlapped and the rising and falling positions approach each other, so that mutual interference that the noise generated in the self circuit by the operation of the self circuit affects the operation of another circuit by an electric connection of the devices and circuits and disturbs the rising and falling timings of another circuit, so-called crosstalk is generated. In application that when 3 to 5 insulating couplers are necessary for the

DAA circuit, the PWM insulating coupler is used for analog data transmission, a waveform distortion is generated by this disturbance and the S/N ratio of the transmission signal is degraded by this distortion.

5 Therefore, for example, in a sound signal, noise increases and in modem application, a transmission error occurs. When the PWM carrier clock timing is synchronized, as shown in the drawing, there is an effect that at least the overlapping of the logic  
10 level timing and the analog signal timing can be separated. Even in a system using only the logic level PWM which will be described later, the disturbance of timing is limited to the neighborhood of the logic level, so that there is an effect that the effect of  
15 crosstalk is minimized.

Fig. 6(b) shows the PWM modulation timing when the principle is applied to a triangular waveform carrier. In this case, in addition to that the PWM modulation timing appears on both sides of the triangular wave  
20 because the carrier shows a triangular waveform, the same problem is basically included. However, when this embodiment is executed, the same effect can be obtained. Since the clock for the insulating coupler  
105 for transferring the termination detection signal  
25 Rdet is generated by the oscillator OSC 112 arranged

on the line side, it does not match with the operation of another insulating coupler in timing. However, since the oscillation is inhibited when the OFHK control signal is inputted and the operation of the oscillation circuit is stopped by this action before the modem communication starts, there is an effect that the effect of crosstalk can be suppressed by it.

Fig. 7 is a conception diagram of layout of this line interface IC. In Fig. 7, numeral 2 indicates a line interface IC and 206-1, 206-2, and 206-3 indicate insulating bands and enclose a line side terminal area 201, a line side circuit area 202, a terminal side circuit area 204, and a terminal area 205 respectively. Numeral 203 indicates the four insulating couplers shown in Fig. 1 which are arranged in one row in the insulating coupler arrangement area.

The characteristics of this layout are (1) four insulating couplers using capacitive insulating barriers are used, (2) the line side circuit and the terminal side circuit are geometrically arranged so that they are separated with the insulating couplers lying between them, and (3) each of the line side circuit and terminal side circuit is enclosed by an insulating band. The insulating band has advantages that the circuits on the line side and terminal side

are insulated and separated respectively by it, and the inside of each area can be freely designed without taking the dielectric strength between the primary circuit and the secondary circuit into account, and  
5 the evaluation and management of the insulating capability are simplified at the same time.

When the package of this integrated circuit is to be mounted, needless to say, it is necessary to secure the insulation distance withstanding air insulation  
10 for the part of the package projected outside and to mold the inside and execute the insulation process.

Next, the structure of the insulation coupler portion shown in Fig. 7 will be explained by referring to Fig. 8. Fig. 8(a) is a plan view, and Fig. 8(b) is  
15 a cross sectional view, and both drawings schematically show only the drive circuit and detection circuit. In Fig. 8(a), numeral 203 indicates an insulating coupler area, 206 an insulating band, 207 an insulating barrier, 211 an input circuit area,  
20 and 212 an output circuit area. The insulating band 206 forms many patterns of 206-1 to 206-6. The portion codes of the insulating barrier 207 are partially omitted because they are complicated but they are the same. The input circuit area 211 and the output  
25 circuit area 212 further comprise PMOS areas 213, 214,

215, and 216 and NMOS areas 217 and 218. As input terminals of the input circuit, two inverter input terminals IN1 and IN2 of the drive circuit are indicated. As output terminals of the output circuit, two inverter output terminals OUT1 and OUT2 of the detection circuit are indicated. VDD1 to VDD4 indicate separated power terminals and VSS1 and VSS2 indicate separated grounding terminals. The characteristics of the plan view (a) are (1) the circuit area is separated by the insulating bands, (2) with respect to the insulating barrier, the insulating bands are formed in a pattern of teeth of a comb so as to reduce the opposed area, and (3) four capacitors are horizontally connected in series so as to form two sets of insulating barriers. These are driven in a complementary PWM digital waveform as mentioned above. There is little crosstalk between the two sets of insulating barriers. However, in the case of a use in which it is questionable, it is effective to provide a long space, a power pattern VDD, and a VSS wiring pattern between the two sets of insulating barriers, that is, horizontally and arrange them between the insulating barriers so as to loose the connection. Even when a plurality of insulating couplers are used, the same arrangement is effective. In the circuit area,

the PMOS areas and NMOS areas are separated by the insulating bands. Even if an unexpected surge voltage is provisionally applied to the circuit due to this separation, a short-circuit or penetration between the power supplies due to continuity of the parasitic transistor, that is, the latch-up phenomenon will not be generated in general.

In Fig. 8(b), numeral 231 indicates a substrate, 232 an insulating layer, 233 a semiconductor layer, and 234 a protection layer, and the semiconductor area is formed by many insulating bands 206, and the input circuit area 211, the insulating barrier 207, and the output circuit area 212 are arranged from the left. In this structure of this embodiment, a silicon wafer (SOI substrate) having an insulating layer of  $\text{SiO}_2$  with a thickness of about 2 microns as an inner layer is prepared and each area is formed on it using the thin-film process using a photo mask. In Fig. 8(b), the insulating bands 206-1 to 206-6 are  $\text{SiO}_2$  layers with a width of about  $1.5 \mu\text{m}$ . Structurally, the areas such as the input and output circuit areas and insulating barrier area are divided and formed by the insulating bands 206 on a silicon wafer having an insulating layer as an inner layer and furthermore the protection layer 234 is overlapped on them. The silicon wafer has

a constitution that one  $\text{SiO}_2$  layer or a multi-layer comprising a polysilicon layer having an oxidized surface overlapped on the aforementioned  $\text{SiO}_2$  layer is overlapped on the substrate 231 of single crystal  
5     silicone and furthermore a semiconductor layer of single crystal silicone is overlapped on it. For bonding the layers, in this embodiment, a method that the surface of a silicon oxide film on the polysilicon surface is mirror-polished and overlapped and then  
10    joined by heat treatment at a specified temperature is used. The insulating bands 206 are  $\text{SiO}_2$  layers and insulators. The protection layer 234 is an insulator of  $\text{SiO}_2$  and HLD or  $\text{SiN}$  and includes a wiring layer using polysilicon or aluminum. The insulating bands  
15    206 are formed by a method for cutting a trench once and filling it with  $\text{SiO}_2$  or BPSG, a method for thinly oxidizing the side wall of a trench and filling it with polysilicon, a method for coating PIQ or SOG, or a method for changing a semiconductor layer to an  
20    insulator by irradiating oxygen ions from the top. The capacitor comprises three electrode areas 236, 237, and 238 and the insulating band 206. By doing this, even in the trenching system that the insulating band 206 is limited to the width compared with the  
25    thickness of the insulating layer 232, the dielectric



strength can be reserved by connecting the capacitor in series.

Even when an electrical request is possibly dielectric strength of one insulating band, by realizing double insulation in this way, a highly reliable part can be obtained. Numerals 235 and 239 indicate the sections of the input circuit area 211 and the output circuit area 212 and these are enclosed by two insulating bands and structured so as to obtain high dielectric strength. Since a plurality of circuits are physically insulated from the substrate by the insulating bands and insulating layer in this way, there is an advantage that this integrated circuit can be directly bonded to the frame during package mounting, hence the heat dissipation is satisfactory.

Next, the structure of the insulating barrier portion of the insulating coupler shown in Fig. 8 will be further explained by referring to Fig. 9. In Fig. 9, (a) is a plan view and (b) and (c) are the cross sectional views A-A' shown in the plan view (a). In Fig. 9(a), numeral 207 indicates an insulating barrier, 206-1, 206-2, and 206-3 insulating bands of  $\text{SiO}_2$  with a thickness of about 1.5 microns, 241, 242, and 243 electrode areas enclosed by the insulating bands 206,

and 244 and 245 terminals which are holes made in the protection layers on the upper parts of the electrode areas 241 and 242. In Fig. 9(b), numeral 231 indicates an Si substrate with a thickness of about 400 microns, 232 an insulating layer with a thickness of about 2 microns, 233 a semiconductor layer with a thickness of about 15 microns, and 234 a protection layer with a thickness of about 5 microns and the other numerals are the same as those shown in (a).

As shown in the cross sectional view, on a silicon wafer having an insulating layer as an inner layer, each area is formed using the thin-film process using a photo mask. The insulating band is an  $\text{SiO}_2$  layer and an insulator. The insulating bands 206 are formed by a method for cutting a trench once and filling it with  $\text{SiO}_2$  or a method for changing a semiconductor layer to an insulator by irradiating oxygen ions from the top. The capacitor comprises the three electrode areas 241, 242, and 243 and the two insulating band 206-1 and 206-3. The insulating bands are patterned by folding each band as shown in the drawing and the capacity can be efficiently obtained with a small semiconductor area by making the contact portion of the electrodes 241, 242, and 243 longer. Incidentally, in this embodiment, the insulation performance is obtained

that the capacity is about 2 pF for a square of about 160 microns and the dielectric strength is about 750 V for each insulating band in the DC withstand voltage test. A high voltage is applied between the terminals 244 and 245 and as viewed from the outside of the insulating barrier 207, a pattern that the electrode areas 241 and 242 are doubly enclosed by the insulating bands is obtained. When forming a pattern of the insulating bands 206, a circular pattern (a radius of 2 to 5 microns) is used for the portions to be folded and the angles as far as possible so as to prevent a sharp pattern. The portion of the insulating band 206-2 is necessary so as to insulate and separate from the other circuit portions. Fig. 9(c) is a structural diagram when each insulating layer cannot be made thicker and by use of two insulating layers, the effective dielectric strength can be increased. In an IC of a multi-layer structure, a considerable warp can be seen. However, by using an insulating multilayer and adjusting the thickness of each layer, an effect is obtained that the stress is dispersed and the warp is reduced.

An example that the insulating couplers are arranged in one row as shown in Fig. 7 is indicated. However, the arrangement of insulating barriers can be

changed as shown in Fig. 10. Namely, Fig. 10 is another layout conception of a line interface IC and as shown in the drawing, respective two insulating couplers are perpendicularly arranged. A test voltage of 1500 VDC is applied between the line side circuit and the terminal side circuit. However, since the circuit areas are enclosed and arranged by the insulating bands respectively on the SOI substrate, a considerably free layout is available.

The layout is restricted by wiring between the areas and arrangement and size of terminals. This layout is characterized in that when the circuit areas and the number of terminals are unbalanced, the areas can be efficiently arranged.

Next, the insulating coupler transmission method of the present invention will be explained by referring to Fig. 11. In Fig. 11, various transmission methods from (a) to (f) are shown using block diagrams. The insulating barriers are the capacitors of the present invention. The insulating coupler of the present invention uses two insulating barriers and is driven by a complementary waveform so that a signal can be precisely transmitted even if the receiver side is floating. The input circuit is supplied with power from the power terminal VDD1 and the grounding

terminal VSS1 and converts and outputs the signal received from the input terminal to the waveform for driving one terminal of the insulating barrier. The output circuit is supplied with power from the power terminal VDD2 and the grounding terminal VSS2, detects the waveform appearing at the terminal on the opposite side of the insulating barrier, and converts and outputs it to an output signal. With respect to a converted waveform, various methods such as the PWM (pulse duty conversion) system for digitizing only the amplitude direction, or the FM system (voltage - frequency conversion) system, or the digital transmission system for also digitizing the time base direction can be used.

Fig. 11(b) shows a case of the PWM transmission system. In the PWM system, the input circuit samples the inputted analog signal in the fixed period  $T$  more than several tens times of the signal band and converts and transmits the amplitude to the duty (0 volt input corresponds to 50% duty) in the time base direction and the output circuit detects it and converts the duty to an amplitude value once again, hence reproduces the input waveform, and outputs an analog signal. By analogically processing the duty, a high resolution in principle can be obtained. Needless

to say, a digital signal may be transmitted.

Fig. 11(c) shows a case of digital transmission of the present invention. In the digital transmission, the code conversion is executed, for example, like the Manchester code so that the same level is not continued in the transmission waveform, and then the insulating barrier is driven, and the output circuit detects it, reversely converts it, and reproduces the original digital signal. In this case, in synchronization with the transfer frequency of the input digital signal, the code conversion and reverse conversion are executed. This method is characterized in that since little conversion is executed in the amplitude direction, it is hard to be affected by noise.

Fig. 11(d) shows a case that AD conversion input is executed via the insulating barrier. The input circuit converts an analog input signal from analog to digital, then performs the same code conversion as that of (c), and drives the insulating barrier. The output circuit detects it, performs reverse code conversion, and then outputs a digital signal.

Fig. 11(e) shows a case that DA conversion output is reversely executed via the insulating barrier. The input circuit performs the same code conversion as

that of (c) for a digital input signal and then drives the insulating barrier. The output circuit detects it, performs reverse code conversion, converts it from digital to analog, and then outputs a digital signal.

5        Fig. 11(f) shows a case that (d) and (e) are combined and input and output of an analog signal are executed by use of AD conversion and DA conversion. The signal transmission system from (d) to (f) is a constitution suitable for the sound signal processing  
10        analog front end of a modem and the line interface when the DSP is selected as a connection destination of a digital signal.

      These systems can be integrated on a monolithic IC by the present invention. More concretely, although  
15        the aforementioned capacitive insulating barrier is a circuit for connecting two circuits, the stray capacity between the insulating barrier and the substrate is large and greatly different from that when the input circuit, output circuit, and insulating  
20        barrier are separately created and combined. Therefore, the transmission efficient by the insulating barrier is low such as 1-severalth. In the aforementioned embodiment, in the first stage of the output circuit, the amplifier circuit is arranged and the detection  
25        process and demodulation process are performed behind

it.

Fig. 12 is a circuit block diagram of the modem device of another embodiment of the present invention.

In Fig. 12, numeral 251 indicates a line interface  
5 IC of this embodiment, 252 a terminal side circuit,  
253 an insulating coupler, 254 a line side circuit,  
and 255 a highly dielectric circuit. The terminal side  
circuit 252 comprises a DSP interface 256, a modem  
data output interface SOR 261, a modem data  
10 compression circuit 262, a sending side multiplexer  
263, a master register GORM 264 of a general purpose  
output register, an error correction circuit 265, a  
receiving side multiplexer 266, a receiving modem data  
expanding circuit 267, a modem data input interface  
15 SIR 268, a general purpose input data error correction  
circuit 269, and a slave register GIRS 270 of a  
general purpose input register. The insulating barrier  
253 comprises a sending path insulating coupler 6-1  
and a receiving path insulating coupler 6-2, and the  
20 line side circuit 254 comprises a multiplexer 271 of a  
line side sending path as a sending path, a sending  
modem data expanding circuit 272, a DA converter 273,  
a general purpose output data error correction circuit  
274, a slave general purpose register 275, an AD  
25 converter 276, an AD conversion data compression



circuit 277, a multiplexer 278, a master general  
purpose input register GIRM 279, an input data error  
correction circuit 280, a 2-wire - 4-wire conversion  
circuit 281, and a switch control circuit 283, and the  
5 highly dielectric circuit 255 comprises a DC loop  
circuit 282 and a call signal detection circuit 284.

The first characteristic of this circuit  
constitution is that the AD converter and DA converter  
are arranged on the line side and a signal passing the  
10 insulating coupler is digital data. As a result, as  
described later, the noiseproof performance when a  
signal passes the insulating barrier is greatly  
improved. The second characteristic is that an AD  
conversion signal and a DA conversion signal are  
15 compressed once and pass through the insulating  
coupler, and a control signal is coded for error  
correction and positioned in this empty portion, and  
the insulating couplers 6 are reduced by half such as  
6-1 and 6-2. When the insulating barrier is mounted on  
20 a semiconductor substrate, a large area is required.  
Therefore, even if an increase in the area due to  
additional circuits for data compression and expansion  
and error correction is taken into account, the  
reduction in the number of insulating couplers is  
25 advantageous for reducing the chip area. Furthermore,

the third characteristic is that the circuit constitution is functionally the same as that shown in Fig. 1 and the internal circuits of the highly dielectric circuit 255 and the 2-wire 4-wire conversion circuit 281 and switch control circuit 283 of the line side circuit 254 have the exactly same functions. The fourth characteristic is that the multiplexer 266 inputs both the reproduced clock of the insulating coupler 6-2 and the clock from the DSP and adjusts the timing. When a 1-bit or 2-bit buffer memory is arranged, the timing can be adjusted. The fifth characteristic is that the general purpose input and output registers GOR and GIR successively transfer contents of the master register to the slave register. Needless to say, as deformation of this circuit, if the art makes progress and the insulating coupler becomes smaller, when the noise reduces and data is not easily mistaken, compression, error correction, and the multiplexer may be omitted.

Next, the effects of this embodiment will be explained by referring to Fig. 13.

In Fig. 13, (a) shows a case that a saw tooth waveform is used as a carrier and (b) shows a case that a triangular wave is used as a carrier. Even if a sending signal and a receiving signal are analog

signals as shown in both drawings, only a digital PWM  
signal passes through the insulating barrier and the  
operation timings of the DSP, modem process, and  
insulating coupler are synchronized, so that the  
5 performance can extremely withstand a transmission  
error by the insulating barrier.

Fig. 14 shows a case that the line interface IC  
comprises two chips. In Fig. 14, numeral 291 indicates  
a line interface chip and 292 indicates a terminal  
10 interface chip. In the line interface chip 291, a  
terminal area 293, a line side high voltage circuit  
area 294, and a terminal area 295 are arranged and in  
the terminal interface chip 292, a terminal area 296,  
a line side low voltage circuit area 297, an  
15 insulating coupler area 298, a terminal side circuit  
area 299, and a terminal area 300 are arranged. In the  
line side highly dielectric circuit area 294, a DC  
loop circuit and a termination (RING) detection  
circuit are arranged. In the line side low voltage  
20 circuit area 297 of the terminal interface chip 292, a  
2-wire - 4-wire conversion circuit, an OFHK switch  
(SW) control circuit, and an originating circuit are  
arranged. By doing this, there is an advantage that by  
separating the process condition of the line interface  
25 chip 291 which is required by a high voltage circuit

device from the circuit of the insulating barrier or a low voltage circuit device, an efficient process can be selected. By reducing the size of one IC chip, there is an effect that the effect of the total yield of the process is reduced and the number of acquired IC chips per wafer is increased. The line interface chip may be used as a discrete circuit using an individual part. By doing this, the terminal interface chip receives only a logic signal and a signal at the modem signal level and the portion to be directly connected to the line is eliminated, so that an effect is produced that the application range can be easily spread such as application to other than the modem, for example, use as an internal circuit of a multifunction telephone set.

Fig. 15 is a structural diagram of another embodiment of the insulation barrier, and (a) is a plan view of single insulation, and (b) is a plan view of double insulation, and (c) is a plan view of another deformed embodiment of double insulation. In Fig. 15, numeral 207 indicates an insulating barrier, 206-1, 206-2, and 206-3 insulating bands, 241 and 242 electrode areas enclosed by the insulating bands 206, 244 and 245 terminals which are holes made in the protection layers on the upper parts of the electrode

areas 241 and 242, and 301-1 and 301-2 partitions.  
Figs. 15(a) and 15(b) show embodiments of patterns of  
insulating bands having no acute angles at all in the  
same way as those of the embodiment shown in Fig. 9.

5           The characteristic of the pattern shown in  
Fig. 15(a) is that the electrode areas 241 and 242  
having the terminals 244 and 245 are formed by drawing  
with a single stroke of the pen by the insulating  
bands 206-1 and 206-2. By doing this, the portion  
10 where the insulating bands are in contact with each  
other in a T shape can be eliminated and there is an  
effect that not only the filling efficiency in a  
groove by the trench method is satisfactory but also  
the concentration of the electric field is reduced.  
15 The same may be said with Fig. 15(b) and the  
characteristic of this pattern is that the electrode  
areas 241 and 242 having the terminals 244 and 245 are  
formed by drawing with a single stroke of the brush by  
the insulating bands 206-3 and 206-4 and these are  
20 further enclosed by the insulating bands 206-1 and  
206-2 respectively. By doing this, intermediate  
electrodes are formed between the insulating bands  
206-1 and 206-3 and between the insulating bands 206-3  
and 206-4, so that there is an effect that two times  
25 of dielectric performance can be realized. The pattern

shown in Fig. 15(c) is a deformation example of the  
embodiments shown in Figs. 15(a) and 9 and if the two  
T-shaped portions are permitted, there is an effect  
that an insulating barrier having a satisfactory area  
5 efficiency can be realized by enclosing by the  
insulating band 206-3. The methods of (a) and (b) can  
be efficiently expanded even when the number of series  
is increased.

The present invention is valid even when a single  
10 insulating coupler is used and it will be explained  
hereunder by referring to Fig. 16. Fig. 16 is a  
structural diagram of an embodiment of the insulating  
coupler of the present invention. An insulating  
coupler 203 shown in Fig. 16 is structured so that a  
15 terminal area 201 for the input circuit and a terminal  
area 205 for the output circuit are provided in the  
portion of the insulating coupler shown in Fig. 8 and  
the respective terminals are arranged and the size  
thereof is a square of about 2 mm. By doing this, a  
20 micro-monolithic insulating coupler part of the analog  
PWM system can be produced. Although the part is  
certainly mounted on a package in the later process,  
it is very small because it is monolithic. Therefore,  
it is mounted within an application device such as a  
25 probe of a measuring instrument and various medical

sensors and can contribute to miniaturization and high performance of these devices.

Fig. 17 is a layout structural diagram when the two insulting couplers shown in Fig. 16 are mounted on one chip. In Fig. 17, numeral 203 indicates a 1-chip  
5 insulating coupler containing two couplers and 203-1 and 203-2 indicate a built-in insulating coupler 1 and insulating coupler 2 respectively and are enclosed by insulating bands 206-1 and 206-2 respectively. The  
10 characteristics of this layout are (1) each insulating coupler is enclosed by insulating bands 62-1 and 62-2 and (2) the insulating barriers in which the electric field is concentrated are lined up. By doing this, the dielectric strength can be secured between any of two  
15 inputs and any of two outputs and there is an effect that each circuit device can be freely arranged with the dielectric strength maintained. By use of this structure, an unnecessary electric circuit connection can be minimized and the application range can be  
20 spread.

Fig. 18 is still another embodiment of the insulating coupler of the present invention and shows the structure of an integrated circuit and insulating coupler when an input circuit and output circuit  
25 insulated by insulating bands respectively are

structured as integrated circuits and an insulating coupler is formed by combining a ceramic capacitor and an insulating barrier. In Fig. 18, (a) shows an outline of chip layout and (b) shows a cross sectional view when the IC and ceramic capacitor are mounted on a circuit substrate. In Fig. 18(a), numeral 303 indicates an insulating coupler IC, 206-1 and 206-2 insulating bands enclosing the input circuit area and output circuit area respectively, and 304 an external insulating barrier and terminal areas 201 and 205 include connection terminals "C1-O and C2-O" and "C1-I and C2-I" with the external insulating barrier 304 respectively. The other numerals have the same meanings as those shown in Fig. 16.

In Fig. 18(b), numeral 303 indicates an insulating coupler IC and 305 and 306 indicate solder. Numeral 307 indicates a circuit substrate having a circuit connection pattern of copper leaf 308, 309, 310, and 311 on both sides and through holes 312 and 313 are provided as required. The circuit substrate 307 may be a multilayer of copper leaf as required unless the insulating property is damaged. An insulating barrier 304 is a chip capacitor and mounted on the surface of the circuit substrate with the solder 316 and 317. By doing this, the insulating barrier occupying a



comparatively large area in the semiconductor integrated circuit is mounted as another chip and the size of the insulating coupler increases. However, a constitution method that a realistic price can be set, and the capacitor value of the insulating barrier is positively increased, and the operation timing frequency can be freely selected is made possible. Namely, the low frequency characteristic is improved by increasing the capacitor value, so that there is an advantage that the waveform can be easily transmitted and for example, small power also can be transferred by a charge pump circuit.

As mentioned above, according to these embodiments, an insulating coupler can be reasonably formed on a semiconductor integrated circuit and the use of an integrated circuit can be widely spread. The insulating coupler formed in this way has an effect that it greatly contributes to miniaturization and low price.

Fig. 19 is a structural diagram showing the concept of an embodiment that the monolithic line interface of the present invention is applied to a card modem device. Fig. 19(a) shows an embodiment of the present invention and Fig. 19(b) shows a conventional card modem. In Fig. 19(a), numeral 400

indicates a whole card modem of this embodiment, 401 a circuit substrate of this embodiment, 402 a line interface IC of this embodiment, 403 an AFE, 404 a DSP, 405 other ICs, 406 a line side connector, 407 a PC side connector, 408 a varister, 409 a highly dielectric capacitor, 410 a capacitor, and 411 to 416 chip parts such as other resistors and capacitors. In Fig. 19(b), numeral 450 indicates a conventional whole card modem, 451 a conventional circuit substrate, 452 a line transformer which is a conventional line interface, 453 an AFE, 454 a DSP, 455 other ICs, 456 a line side connector, 457 a PC side connector, 458 a varister, 459 a highly dielectric capacitor, 460 a capacitor, and 461 to 466 chip parts such as other resistors and capacitors. This drawing shows the section of the card modem which is schematically indicated and the comparison shows that in the conventional card modem 450, the circuit substrate 451 is hollowed out and the line transformer 452 is arranged in the hollowed portion, while in the embodiment of the present invention, the line interface IC 402 can be mounted almost in the same way as the other ICs shown in from 402 to 405. Therefore, it is not necessary to hollow the circuit substrate 401 and the present invention is economical. Since a

special transformer is not used, there is the possibility that the constitution can be made economical. Furthermore, since the transformer can be omitted, there is a possibility of further  
5 miniaturization.

Fig. 20 is a circuit block diagram of an embodiment when the monolithic digital insulating coupler of the present invention is applied to an AFE. The AFE of this embodiment is used for processing a  
10 voice band signal and performs oversample (2 MHz) AD and DA conversion as analog and digital conversion, reduces the speed to 32 ksps once by a decimeter filter and interpolator, furthermore performs the low pass filtering process by the internal DSP, and  
15 finally inputs or outputs digital data at a speed of 8 ksps.

In Fig. 20, numeral 500 indicates a monolithic analog front end (I-AFE) containing digital insulating couplers 501 to 506. The I-AFE 500 comprises an analog  
20 input line including a multiplexer (MUX) of the original AFE, a pad amplifier (PDA) 512, a prefilter (PF1) 513, an oversample analog to digital converter ADC 514, a decimeter filter (DCM) 515, an AD conversion output buffer (ADCR) 516, a built-in (in-) DSP 517, and a receiving output buffer (RXDR) 518, an  
25

analog output line including a sending buffer (TXDR) 521, a DA conversion input buffer (DACR) 522, an interpolator (INT) 523, an oversample digital to analog converter DAC 524, a post filter (PF2) 525, and  
5 an attenuator (ATT) 526, data I/O transfer controllers 531 and 532 of the in-DSP 517, and a 2-wire - 4-wire conversion circuit 533 at an analog I/O terminal with a control circuit added. The inside of the I-AFE 500 is reset or controlled in power down by a control  
10 circuit (CONT) 541. A reset signal is transmitted to the circuit on the left (hereinafter referred to as the analog I/O side) via the digital insulating coupler 506, combined with a reset signal following power ON or OFF on the analog I/O side by a reset  
15 circuit 542, and used as a reset signal for the circuit on the analog I/O side. To finely control the I-AFE 500, an external device uses control registers (CONTR) 551 and (STATUS) 554. The content of the CONTR 551 (STATUS' 553) is copied into the control registers  
20 (CONTR') 551 and STATUS 554 of the analog (digital) I/O circuit via the digital insulating couplers 504 and 503 and controls SW1 to SW3 of the analog I/O side circuit and other circuits and sets the level of a general purpose output port (GPO). The operation  
25 timing of the I-AFE 500 is converted to 8-fold 16 MHz

by a 2-MHz clock (MCLK) PLL given by an external (ex-) DS0 536 and used as basic timing together with the inputted 2 MHz. Needless to say, it is also transmitted to the analog I/O circuit via the digital  
5 insulating coupler 505 and various timings are generated by a timing circuit 562.

A reference voltage generation circuit 563 is a circuit for giving a reference voltage to the analog I/O circuit for operating by a single power supply and  
10 generates a reference voltage VREF of  $(VDD1 - VSS1)/2$ .

Next, the operation will be explained. The 2-wire - 4-wire conversion circuit 533 is a circuit for exchanging 2 wires of the pay station line and 4 internal sending and receiving wires when the I-AFE  
15 500 is used in a mode device and has functions of line impedance matching and I/O amplification. An analog input signal is inputted via the 2-wire - 4-wire conversion circuit 533 or directly inputted from the IN+ and IN- terminals. However, the MUX 511 is  
20 switched and used by a signal SW1 beforehand according to one of them. The PDA 512 can switch the gains 0 dB and 6 dB by a signal SW2.

The PF1 513 is an analog filter for deleting a signal of an unnecessary frequency band before  
25 performing AD conversion and a secondary low pass

filter at a cut-off frequency 48 kHz in this  
embodiment. The ADC 514 is a secondary  $\Delta\Sigma$  modulator  
operating at 2 Msps and outputs an AD conversion  
result 2 bits long every 0.5  $\mu$ s. The ADC 514 transmits  
5 this AD conversion output to the DCM 515 and thins it  
to 2 ksps. The output of the DF1 515 is 16 bit/w.  
However, the speed is slow such as 32 ksps, so that  
the DF1 515 serially converts it to 2 Msps and  
transmits it to the in-DSP 517 via the ADC 516 of the  
10 I/O side circuit together with the timing signal via  
the insulating coupler 502. The in-DSP 517 performs  
the flat characteristic correction for this decimeter  
output by the digital signal processes IIR and FIR and  
performs the LPF process at 4 kHz or less. The in-DSP  
15 517 serially transmits the processing result to the  
ex-DSP 236 as 16-bit/w data for every 8 ksps via the  
receiving buffer 518.

Next, the analog output line receives the data  
(TXD) to be outputted from the ex-DSP 536 from the  
20 sending buffer TXDR 211 every 8 ksps, performs the  
same filtering process as that of analog input by the  
in-DSP 517, and transfers this result to the  
interpolation filter (INT) 523 at a speed of 32 ksps  
by interpolating it as 16-bit/w data via the DA output  
25 buffer (DACR) 522. Also in this case, the analog

output line performs serial conversion and transmits the data via the insulating coupler 501. The INT 523 further performs the interpolation process, transfers it to the DAC 514 as 6-bit/w data at a speed of 2 Msps, and outputs an analog value. The loopback component remaining by the process by the in-DSP 517 and the INT 523 is removed by the post filter PF2 525 and outputted via the ATT 226 which can switch 0 dB, -6 dB, and  $-\infty$  dB. For these operation timings of the analog output line, the timings of the analog input line are used.

These processing timings are timings that the processing timing of the  $\Delta\Sigma$  modulator and demodulator of basically the same timing among the 2-MHz timings, the interpolator and decimeter processing timing to be inputted and outputted at 2 Msps and 32 ksps, and the DSP processing timing to be inputted and outputted at 32 ksps and 8 ksps are allocated in order. Therefore, the analog I/O side circuit and digital I/O side circuit are separated by the insulating couplers 201 to 205. However, it is essential to synchronize and operate them and this is the reason why it is important to set an isolator only for timing.

Next, application of the I-AFE 500 to a modem together with the ex-DSP 536 will be explained.

The I-AFE 500 viewed from the ex-DSP 536 is an I/O circuit of an analog signal and the sample timing is important. Therefore, in most modems, the sample timing of the ADC 514 is adjusted so that a most  
5 advantageous timing for discrimination and decision can be obtained during demodulation. Therefore, delay or advance of the timing is transmitted to the I-AFE 500 from the ex-DSP 536 by the clock MCLK. Namely, to advance the timing,  $\Delta f$  is added and to delay the  
10 timing,  $-\Delta f$  is added and the I-AFE 500 is informed of it. This process is performed every several tens ms or several hundreds ms. When the I-AFE 500 operates at a selfish timing, it does not agree with the timing requested by the ex-DSP 536, so that data becomes too  
15 much or too little, and the processing time breaks down, and large noise is generated. To synchronize the I-AFE 500 with this clock delaying or advancing, the PLL is installed inside the I-AFE 500 so as to synchronize the internal timing. Needless to say, if  
20 the timing accuracy request permits, there is a complementary method available using the timing error of the automation means in the modem and in this case, the circuit timing adjustment is not executed.

In this embodiment, data transfer between the  
25 decimeter filter and interpolator and the in-DSP is



serial high-speed transfer, so that there is an effect  
that the number of insulating couplers is decreased.  
Since the modem includes a plurality of standards, a  
plurality of sample timings may be requested. To  
5 respond to it, the division ratio of the PLL 561 and  
the timing circuit 562 can be controlled by the CONTR  
562. Furthermore, by applying the aforementioned error  
correction means to the insulating couplers to which  
the control signal is transferred, the operation can  
10 be stabilized.

In this embodiment, a constitution that the  
digital filter is signal-processed by the internal DSP  
517 is indicated. The process of the internal DSP is a  
dedicated process for AD conversion and DA conversion  
15 and these circuits may be formed by appropriate  
dedicated logic. When those circuits comprise  
dedicated logic, more economical integration may be  
realized. The two systems of analog input line and  
analog output line may be processed by one processing  
20 means.

Next, the layout concept on the integrated circuit  
shown in Fig. 20 is shown in Fig. 21. In Fig. 21, a  
whole 600 indicates the whole AFE integrated circuit  
and it is formed on an SOI substrate. An insulating  
25 band 601 is a means for insulating the analog I/O

circuit area, and an insulating band 602 is a means  
for insulating the insulating couplers (indicated by  
isolators 501 to 506), an insulating band 603 is a  
means for insulating the digital I/O circuit area, and  
5 an insulating band 604 is a means for insulating  
between other chip areas on the wafer and the areas  
and the insulating band 604 is a means for preventing  
circuit connection with the substrate linking with the  
scribe end face. The names assigned to more finely  
10 divided areas in each area correspond to Fig. 20  
respectively.

The characteristics of this layout are that the  
circuit areas are further enclosed by trenches so as  
to form an analog I/O side circuit area 601, an  
15 insulating coupler area 602, and a digital I/O side  
circuit area 603, and (1) a double trench is formed  
between each areas so as to insulate between the areas,  
and (2) furthermore the whole is enclosed by a trench  
604 so as to insulate between the chips. The trench  
20 604 is a multitrench.

By enclosing each circuit block in the circuit  
areas 601 to 603 by a trench, the circuits are  
insulated and separated from each other and the  
devices are separated. However, when furthermore a  
25 multitrench is used and the trenches are grounded, a

noise shield due to mutual interference can be formed. By making the multiplexing rate of trenches in the circuit area higher one step than the multiplexing rate of trenches in the highly dielectric capacitor portion, the insulation cooperation is taken into account so as to limit the destruction mode to the capacitor portion. By doing this, even if a high voltage more than the standard is applied, there is an effect that a system can be constructed with the damage limited.

Next, Fig. 22 is a circuit diagram of an embodiment of a DSP modem to which the I-AFE shown in Fig. 20 is applied. In Fig. 22, numeral 500 indicates I-AFE and 700 indicates ex-DSP. When the modem is connected to a telephone line, it is connected to connection terminals TIP and RING via a protection circuit comprising resistors 701 and 702, capacities 703 and 704, and a surge protection device 705. Numerals 706 and 707 indicate switches formed by NMOS transistors and they are connected to a photo detector (for example, a solar cell) 708. The photo detector 708 receives light of a light emission diode 709, turn 706 and 707 on or off, and supplies power supplied via TIP and RING to the circuit on the right of the switches. The light emission diode 709 is controlled

in light emission by the switch circuit comprising a transistor 710 and resistors 711 and 712. The control signal of this switch is POWER ON. Diodes 713, 714, 715, and 716 constitute a bridge and have a function  
5 for keeping the current direction constant regardless of the direction of the DC voltage applied to TIP and RING. The circuit comprising resistors 717 and 718, a capacity 719, transistors 720 and 721, a resistor 722, and an NMOS transistor 723 is a DC loop circuit, and  
10 when the control output terminal GPO of the I-AFE 500 goes high, the NMOS transistor turns on, and Darlington transistor circuits 720 and 721 operate according to the bias of the resistors 717 and 718 and flows a loop (looping) current balanced with the  
15 feedback resistor 722. The circuit comprising a resistor 724 and a 18-V Zener diode 725 is a protection circuit for preventing application of an excessive voltage to a 3-terminal regulator 726 and the I-AFE 500. A capacity 727 is a smoothing capacitor  
20 and capacities 728 and 740 are an output circuit of I-AFE and a signal connection capacitor.

When sending by the modem, the POWER ON signal is generated first, and the NMOS switches 706 and 707 are turned on, and the 3-terminal regulator 726 is  
25 connected to the line, and a current is supplied to

the AFE, and the GPO is put on the high level from the  
TXD via the CONTR next, and the NMOS switch 723 is  
turned on, and the loop current is conducted so as to  
notify the switchboard of the office that the modem is  
5 connected to the line. Next, the modem sends a dial  
signal to the I-AFE 500 via the capacities 728 and 440  
and waits until the switchboard connects the remote  
modem. The connected remote modem generates the normal  
modem signal, so that the modems mutually perform  
10 communication via the AFE hereafter. The capacity 729  
and Zener diodes 730 and 731 are a sensitivity  
adjustment circuit for rejecting a response to an  
incoming signal at lower than the fixed voltage, and  
the resistor 732 is a current limit resistor of the  
15 diode 733 or the light emission diode 734, and the  
photo transistor 735 detects emitted light and  
notifies the modem 700 of it as a RING DETECT signal  
when an incoming signal flows in the light emission  
diode 734 through a load of the resistor 736. During  
20 reception of the modem, this signal is notified to the  
modem, and the POWER ON terminal responds to it, and  
the NMOS switches 706, 707, and 723 are turned on, and  
the loop current is conducted, and the power is turned  
on, and a modem response signal is repeated via the  
25 capacities 728 and 740. Hereafter, the modem signal is

sent and received almost in the same way as that during sending.

According to the embodiments explained in Figs. 20 to 22, the following characteristics and effects can be obtained. The first characteristic is that the analog I/O side circuit including the circuit of individual parts on the left of the arrangement of insulating couplers of the I-AFE all insulates the digital I/O circuit on the right. Conventionally, the circuit is insulated by an insulating transformer and if anything, located on the right. The transformer can be deleted by the I-AFE in this embodiment and a miniature modem device can be constructed. The second characteristic is that power is supplied to the analog I/O side circuit of the I-AFE from the office and the power is supplied. Therefore, it is not necessary to supply the power of the analog I/O device from the modem device side and it contributes to reduction in the whole power consumption. The third characteristic is that the switches of the individual part portion are divided into the POWER ON switches 706 and 707 and the loop current switch 723. By doing this, power is supplied to the AFE without conducting the loop current at start of line connection and for example, it can be used for sending and receiving a signal

between the switchboard and the modem such as notification of the originating number.

The insertion position of the insulating coupler in the AFE may be changed from that shown in Fig. 20.

5 For example, the insulating couplers are arranged between the ADC and DAC and the decimeter filter and interpolator. The data transfer speed in this portion is fast such as  $2 \text{ bit/w} \times 2 \text{ Msps}$  or  $6 \text{ bit/w} \times 2 \text{ Msps}$ , so that the insulating couplers are installed in  
10 parallel. Therefore, the delay time due to the transfer operation can be almost ignored. As a result, for example, when an echo canceller or the terminal is to be processed by the in-DSP, there is an advantage that the processing performance is little restricted  
15 compared with the case shown in Fig. 20.

As an ON-OFF control circuit for the NMOS switches 706 and 707, a charge pump circuit may be used. The charge pump circuit comprises a plurality of capacities, a driver for supplying electric charge to  
20 the capacities, and a plurality of switches for controlling electric charge supply and is a circuit such that by repeating an operation at high speed that electric charge is supplied to a capacity by the driver and switch and the electric charge is moved to  
25 another capacity by changing the switch, another

capacity obtains a voltage. When this charge pump circuit is applied to the circuit shown in Fig. 22, by adding the insulating barrier of the present invention, an inverter driver, and a switching diode, an ON-OFF control circuit can comprise only a silicon semiconductor device. Therefore, the ON-OFF control circuit can be integrated on the SOI substrate together with the I-AFE, so that the number of parts of the modem device can be decreased furthermore.

10       An application example of insulating couplers to the AFE is described above. According to this embodiment, as mentioned above, although 8 to 13 insulating couplers are used for the I-AFE, there is an effect that the area of chip layout can be made smaller such as less than 10% of the total area of the AFE. Needless to say, a constitution may be used that by operating and using insulating couplers at high speed of a multiple of the number of rows, the number of insulating couplers to be used is decreased. In either way, the effect of remarkable miniaturization is kept unchanged compared with a case that an insulating coupler using an insulating transformer and external highly dielectric capacitor is used. Since this integrated circuit is suited to mass production, it is also characteristic that the economical



efficiency can be improved. Particularly, a recent high speed modem requires high performance of a transformer, hence an expensive material such as permalloy is used as a core material, so that 2 or 3 fold part expenses are required compared with a case that an inexpensive silicon steel plate is used. In this meaning, when this embodiment is applied, in the high-speed modem field, there is an effect that the present invention greatly contributes to not only miniaturization but also improvement of economical efficiency. As mentioned above, according to this embodiment, there is an effect that a very miniature on-chip highly dielectric capacitor or a very miniature monolithic insulating coupler can be realized, and a miniature AFE can be realized by use of it, and a miniature and economical modem device can be realized by use of the AFE.

Fig. 23 is a structural diagram of an embodiment of a communication system using a combination of a modem device and a host (PC). In Fig. 23(a), numeral 810 indicates, for example, the portion of the discrete circuit shown in Fig. 22 and it is a DAA (direct access arrangement) means including a protection device, connection switch, DC loop circuit, DC loop switch (DC loop), and call signal detection

circuit. Numeral 811 indicates insulating, filtering, AD, and DA means like the I-AFE, 812 a modulation and demodulation means like the DSP, and 813 a transmission control means comprising an MPU, memory, and software and a modem section 800 comprises these units. Numeral 801 indicates an application control means such as a PC and it is a whole control CPU of the internal host CPU of the WS, PC, and PDA, the dedicated DSP, or the cluster modem and it is called a PC basic section or host here.

As an application control means, in addition to the aforementioned, there are various digital devices handling a digital signal and terminal devices available.

Fig. 23(a) shows an embodiment using I-AFE in the constitution that the signal process is hierarchically divided among the DSP, MPU, and PC, so to speak, the conventional type modem constitution, and the expensive and large insulating transformer which is conventionally installed in the DAA is deleted by the I-AFE, and the number of photocouplers is decreased, and the embodiment contributes to miniaturization and improvement of economical efficiency. The monolithic insulating couplers are built in the AFE. However, they may be structured so as to combine with another

part as required. The I-AFE and DSP may be integrated.

Fig. 23(b) is a structural diagram of an embodiment of a soft modem device using I-AFE. In Fig. 23(b), each same numeral as that shown in Fig. 23(a) indicates the same name, and numeral 822 indicates an interface (I/F) means for connecting the modulation and demodulation means 811 and the application control means 803 and it includes a buffer memory about 0.5 MB long and another control logic circuit. The characteristic of this constitution is that by processing the modulation and demodulation means and transmission control means in a batch by the host CPU, the hardware of the modulation and demodulation means (DSP) 812 and the transmission control means (MPU) 813 is reduced and substantial miniaturization and improvement of economical efficiency of the modem device are realized. In this constitution, since the hardware of the modem section is made smaller, the effect of miniaturization and improvement of economical efficiency by the monolithic insulating couplers is seen conspicuously large. Even in this constitution, the monolithic insulating couplers may be combined with other than the AFE. The I/F means has a main function for temporarily storing AD and DA conversion data and if it is integrated with the I-AFE,

the modem device can be miniaturized more. On the other hand, the I/F means 822 may be integrated with the application control means 803. In the note PC, PDA, and cluster type modem device in which the modem  
5 section and the PC section are integrated, the classification of the modem section is originally thin and the arrangement may be decided at the request of others.

As mentioned above, in a modem device and a  
10 communication system using a modem, it is clear that by using I-AFE, that is, monolithic insulating couplers, the insulating transformer can be deleted, and the number of photocouplers can be decreased, and miniaturization and improvement of economical  
15 efficiency of the equipment can be realized.

As a boundary between the modem section and the PC section, in the respect of standardization, there are a parallel bus like the PCI standard and a serial bus like the IEEE1394 or USB, and the establishment of a  
20 constitution suited to these buses is effective in spreading of application of the present invention, and an effect of miniaturization and improvement of economical efficiency is produced.

Fig. 24 is a system block diagram of still another  
25 embodiment. In Fig. 24, numeral 850 indicates a

controller, 860 to 862 insulating couplers, 851 a  
transceiver, and 852 a power regulator and these units  
constitute one station 840. Numeral 841 indicates  
another station whose inside is not disclosed and a  
5 plurality of other stations not shown in the drawing  
are assumed. These stations are connected to a network  
bus 870 including a signal bus 871, a power bus 872, a  
control signal bus not shown in the drawing, and a  
power supply 880 respectively in parallel. In these  
10 stations, the controller and application circuit  
(controller side circuit portion) 850, the transceiver  
851, and the power regulator 852 (network side circuit  
part) are insulated and separated by the insulating  
couplers 860 to 862 and the transceiver 851 connects  
15 the controller and application circuit 850 and the  
signal bus 871 via the insulating couplers 860 to 862  
so that the network side circuit portion supplies  
power from the power bus 872. The insulating couplers  
connect the controller and application circuit 850 and  
20 the transceiver 851 and controls the standby operation  
of the transceiver 851. To execute communication  
between a certain station 840 and another station,  
when the station to be started releases the standby of  
the transceiver and monitors a receiving signal R, it  
25 becomes aware of that the signal bus 871 is free and

sends a sending signal T addressed to another station.  
Another station releases the standby of the  
transceiver sometimes, monitors the receiving signal R,  
monitors the status of a control signal of a network  
5 bus not shown in the drawing, and checks whether it is  
a signal addressed to the own station. If it is, the  
station controls so as to receive the signal next.  
This control sequence is an example and can be changed.  
What may be safely said commonly to those devices  
10 connected to the network is insulation and separation  
of the network and station. Namely, for the network  
and terminal, in the same way as with the modem, even  
if an abnormal voltage is generated due to an abnormal  
situation in others, it is essential to prevent its  
15 diffusion and an expensive transformer and  
photocoupler are conventionally used as this  
insulation means. Therefore, a problem of  
miniaturization and improvement of economical  
efficiency arises.

20 When monolithic insulating couplers are applied  
like this embodiment, there is an advantage that not  
only miniaturization and improvement of economical  
efficiency can be realized as a system but also by  
realizing an IC by appropriate combination with the  
25 controller circuit and transceiver circuit,

miniaturization and improvement of economical efficiency also can be realized as a circuit.

As explained in this embodiment, according to the present invention, there is an advantage that  
5 miniaturization and improvement of economical efficiency can be realized not only for the modem device but also for the network device.

In these examples, an example that power is supplied from the network is explained. However, if  
10 another communication system or device is insulated from the application circuit side and power is supplied, the present invention also can be applied to it. In this case, the effect of improvement of economical efficiency may be slightly reduced, but the  
15 present invention may be effective including an advantage of miniaturization.

Fig. 25 is a layout diagram of insulating couplers corresponding to Fig. 16 when T-shaped or Y-shaped connection of an insulator is permitted as shown in  
20 Fig. 15(c) instead of drawing with a single stroke of the pen. In Fig. 25, numerals 201 to 207 indicate the same names as those shown in Fig. 16. An insulating band 206' has Y-shaped joints at the six circled portions and one input circle area, two insulating  
25 barriers, and one output circuit area are insulated

and separated by the joints respectively. When the insulator 206' is arranged in this way, for wiring between the input circuit and the insulating barriers and between the insulating barriers and the output circuit as shown in Fig. 16, there is an effect that there is no need to consider insulation between the area among the areas requiring to consider high insulation and the intermediate electrode area of the insulating barriers.

Fig. 26 is a block diagram of a digital insulating coupler of an embodiment of the present invention.

Firstly, the primary circuit area, insulating barrier, and secondary circuit area are insulated and separated on one semiconductor substrate. Pls\_in and Pls\_out indicate an input pulse signal and output pulse signal of the insulating barrier respectively. Numeral 901 indicates a differential amplifier circuit for generating a complementary pulse signal on the basis of the input pulse signal Pls\_in. Numeral 902 indicates a capacitive insulating barrier for coupling a complementary pulse signal driven by the differential amplifier circuit 901 to the secondary side with a high dielectric strength. Numeral 903 indicates a differential circuit for differentiating a signal coupled from the primary side by the insulating



barrier 902. Numeral 904 indicates a transition  
detection circuit for inputting a pair of signals  
differentiated by the differential circuit 903 and  
detecting and amplifying each edge of the pair of  
5 differential signals. Numeral 905 indicates a pulse  
regeneration (demodulation) means for regenerating  
(demodulation) the input pulse signal Pls\_in using an  
output signal of the transition detection circuit 904  
and outputting the output pulse signal Pls\_out.

10 In this embodiment, by structuring all the  
circuits including the insulating barrier 902 inside  
the monolithic IC, insulating and separating the  
primary circuit area, insulating barrier, and  
secondary circuit area, and forming them on the same  
15 semiconductor substrate, miniaturization of the  
digital insulating coupler can be realized. In this  
embodiment, a digital insulating coupler is used  
because a signal is transferred from the primary side  
to the secondary side by a digital signal. However, by  
20 installing an AD conversion circuit and a DA  
conversion circuit in the input section and output  
section of this embodiment, an analog insulating  
coupler can be easily realized.

Fig. 27 is a concrete circuit diagram of a digital  
25 insulating coupler of an embodiment of the present

invention.

Fig. 28 is a drawing showing the operation waveform of the circuit shown in Fig. 27. The operation of the circuit of a concrete embodiment of the digital insulating coupler of the present invention will be explained by referring to Figs. 27 and 28.

In Fig. 27, numeral 910 indicates a differential amplifier circuit for inputting an input pulse signal Pls\_in and outputting a complementary paired pulse signal Pls\_1. The first stage comprises a CMOS differential amplifier and outputs the comparison result of the reference voltage Vref with the input pulse signal Pls\_in as a complementary signal. The driver at the next stage (drive stage) comprises a CMOS inverter and outputs the complementary paired pulse signal (output of the differential amplifier circuit) Pls\_1 having an amplitude almost equal to that of the supply voltage by it. Numeral 920 indicates a capacitive insulating barrier having dielectric strength between the primary side and the secondary side. At each terminal on the primary side and secondary side, a reverse connection diode is provided between the terminal and the high potential power supply (VDD1 or VDD2) and between the terminal

and the low potential power supply (VSS1 or VSS2) respectively as a means for absorbing a surge due to noise. The insulating barrier itself comprises, as mentioned above, a highly dielectric capacity (capacitor) formed within the same semiconductor integration device. Numeral 930 indicates a load resistor forming a differentiation means provided at the secondary terminal so as to output a differential waveform by the capacitive connection from the primary side. The load resistor is provided so as to short-circuit between the high potential power supply VDD2 and the secondary terminal. Therefore, the secondary terminal is stationarily fixed at the potential of the high potential power supply VDD2 and when the primary terminal shifts from the "Hi" level to the "Lo" level, a spike-shaped differential waveform is generated on the "Lo" level side. Numeral 940 indicates a transition detection circuit for inputting a paired differential signal Pls\_3, detecting both of the leading edge of the input pulse signal Pls\_in and the trailing edge, and generating a one-shot pulse Pls\_4. The input stage uses a pair of CMOS differential amplifiers for reversely connecting the paired differential signal Pls\_3 mutually as input signals. Each of the pair of CMOS differential amplifiers

outputs a single end signal. An input signal of the CMOS differential amplifiers is stationarily on the same level, so that the load comprises a PMOS current mirror.

5           Only when a potential difference is generated in the paired differential signal Pls\_3 (the input pulse signal Pls\_in shifts), the CMOS differential amplifiers output a differential output (each CMOS differential amplifier outputs a single end output)  
10   Pls\_40 for the potential difference. Therefore, the outputs Pls\_40 of the pair of CMOS differential amplifiers are stationarily on the same level. As a result, it is necessary to design so that the PMOS input level conversion circuit at the next stage does  
15   not output the intermediate level (level in the neighborhood of the logical threshold value of the gate at the nest stage) when the input signal is on the same level. For example, in this embodiment, since the pulse reproducing (demodulation) circuit  
20   comprising a flip-flop at the next stage receives at the CMOS NAND gate, the MOS gate width of the level conversion circuit is designed so as to output the "Hi" level when Pls\_40 is on the same level. Therefore, the level conversion circuit operates so that the  
25   ratio of the gate width  $W_{p1}$  of PMOS1 on the input side

to the gate width  $W_{n1}$  of NMOS1 will not be equal to the ratio of the gate width  $W_{p2}$  of PMOS2 on the output side to the gate width  $W_{n2}$  of NMOS2. Both outputs of the transition detection circuit 940 are stationarily on the "Hi" level and the transition detection circuit 940 generates a one-shot pulse on the "Lo" level in one output during rising and a one-shot pulse on the "Lo" level in the other output during falling in correspondence with transition of the input pulse signal  $Pls\_in$ . Numeral 950 indicates a pulse reproducing circuit comprising a flip-flop for reproducing the input pulse signal  $Pls\_in$  on the secondary side by the output signal  $Pls\_4$  of the transition detection circuit and outputting the output pulse  $Pls\_out$ . This embodiment is an example that a flip-flop comprising two sets of CMOS-NAND gates and a driver of a set of CMOS inverter constitute a pulse reproducing circuit. A means for resetting the flip-flop may be installed as required.

In the insulating coupler of this embodiment, the secondary terminal is short-circuited to the high potential power supply  $VDD2$  via the load resistor, so that the primary falling operation is important. Therefore, in the CMOS inverter at the output stage of the differential amplifier circuit 910, for example,

when the logical threshold value VLT is set less than  
(VDD-VSS)/2 like the CMOS inverter, the falling  
transition time is shortened and variations of the  
timing can be suppressed. In the explanation of this  
embodiment, the delay time of the circuit is not  
mentioned. However, the delay time of the circuit is  
sufficiently short compared with the pulse width of  
the input pulse signal relating to the explanation of  
operation and although there is a delay time of the  
circuit, it is not particularly taken into account.

According to this embodiment, since the components  
of the circuit are all installed within the same  
semiconductor integration circuit device,  
miniaturization, improvement of economical efficiency,  
and high reliability can be realized. In this  
embodiment, the circuits before and after the  
insulating barrier comprise differential circuits, so  
that the common mode noise resistance can be increased  
and the SN ratio can be increased. When the circuit  
behind the insulating barrier comprises a pair of  
differential amplifiers, an amplifier circuit  
excellent in CMRR can be realized. CMRR is an  
abbreviation for Common Mode Rejection Rate and means  
the so-called in-phase signal removal ratio.  
Furthermore, the circuit comprises a simple CMOS gate,

so that there is an effect that it can sufficiently respond to a low voltage of less than 5 V (down to about 1.8 V) and the power consumption can be suppressed.

5           A substrate of an SOI wafer is generally used in the state that it is originally grounded. However, when the substrate is set at a floating potential, buried insulating layers are doubly installed between the input circuit and the output circuit and more  
10 highly dielectric strength can be obtained. However, on the other hand, the following problem is imposed.

Fig. 29 shows a means for reducing the effect of crosstalk between some insulating couplers which poses a problem when a plurality of insulating couplers are  
15 mounted on the same SOI semiconductor substrate and the substrate is set at a floating potential.

In Fig. 29, [1] IN1 and [2] IN1 indicate signal input terminals of insulating couplers 961 and 962 and [1] OUT2 and [2] OUT2 indicate signal output terminals  
20 of isolators 961 and 962. Terminals POWER1 and POWER2 are power terminals for supplying power to the primary circuit and secondary circuit of the insulating couplers respectively and connected to a substrate 965 of an SOI wafer by capacities 963 and 964 respectively.  
25 Capacities 966 and 967 are stray capacities existing

between the insulating couplers 961 and 962 and the substrate 965 and the greater part of them is a coupling capacity between the insulating barriers and the substrate. In this constitution, when the first  
5 insulating coupler 961 operates, a leaked signal component is generated in the substrate via the capacity 966 and there is a fear that it may affect the operation of the second insulating coupler by the capacity 967 and the coupling capacity between the  
10 secondary circuit not shown in the drawing and the substrate. However, in this case, since the capacities 963 and 964 are connected, the noise generated in the substrate is absorbed in the low-impedance power supply via these capacities. Even if these insulating  
15 couplers are reverse, the same may be said. When the capacities 966 and 967 are 1 pF and the capacities 963 and 984 are 100 pF to 1000 pF, a remarkable effect can be obtained. In this embodiment, the capacities 963 and 964 are explained as different parts from the  
20 semiconductor. However, when the circuit area other than the insulating couplers is large like I-AFE and the respective coupling capacities between the primary circuit and secondary circuit and the substrate are large as a result, addition of a capacity is not  
25 necessary. Even when a plurality of insulating



couplers face in different directions, the same action effect can be obtained.

As explained above, according to this embodiment, there is an effect that when the substrate is at a floating potential, if the coupling capacities between the primary circuit and secondary circuit and the substrate are made larger or a large capacity is connected between the substrate and the power supply outside the semiconductor, the effect of crosstalk can be reduced.

Most highly dielectric performance when the substrate is set at a floating potential can be obtained when the coupling capacity between the substrate and the input circuit is equal to the coupling capacity between the substrate and the output circuit. If the capacities cannot be well-balanced under some conditions, the aforementioned external capacity can be used in addition to the crosstalk countermeasure. As this capacity, a surge absorption device may be used. In this case, in addition to the aforementioned effect, a surge suppression effect is obtained.

#### INDUSTRIAL FIELD OF APPLICATIONS

According to the present invention, a miniature insulating coupler and modem interface circuit of high

performance and a miniature and economical modem device can be realized.

WHAT IS CLAIMED IS:

1. A modem device for modulating and demodulating a signal between application control means and a line, wherein said device has an insulating coupler for separating said application control means and said line by a capacitive insulating barrier and at least said capacitive insulating barrier is formed on an SOI substrate.
2. A modem device according to Claim 1, wherein said device has a line side circuit for inputting and outputting a signal between said line and a line connected to said line, a DSP for modulating or demodulating an I/O signal, and an analog-digital interface between said line side circuit and said DSP.
3. A modem device according to Claim 2, wherein said insulating coupler is connected between said line side circuit and said analog-digital interface and said line side circuit and said insulating coupler are integrated on said SOI substrate.
4. A modem device according to Claim 2, wherein said insulating coupler is connected between said analog-digital interface and said DSP and said line side circuit, said analog-digital interface, and said insulating coupler are integrated on said SOI substrate.

5. A modem device according to Claim 2, wherein a charge pump circuit using said capacitive insulating barrier drives a CMOS switch and controls said line side circuit.

5        6. A modem device according to Claim 2, wherein a termination detection signal path is controlled by turning a DC loop control signal on.

7. A modem device according to Claim 2, wherein a control signal and DA conversion or an internal state  
10        signal and an AD signal are multiplexed.

8. A modem device according to Claim 2, wherein a sound band signal is compressed.

9. A modem device according to Claim 2, wherein the operation timings of said line side circuit, said  
15        analog-digital interface, and said insulating coupler are synchronized with the operation clock of said DSP.

10. A modem device according to Claim 2, wherein a control signal is changed to an error correction  
20        code and then a signal is transmitted via said insulating coupler.

11. A modem device for modulating and demodulating a signal between application control means and a line, wherein said device has a line side circuit for inputting and outputting a signal between  
25        said line and a line connected to said line, a DSP for

modulating or demodulating an I/O signal, an analog-  
digital interface between said line side circuit and  
said DSP, and an insulating coupler for separating  
said application control means and said line and the  
5 operation timings of said line side circuit, said  
analog-digital interface, and said insulating coupler  
are synchronized with the operation clock of said DSP.

12. A modem device according to Claim 10, wherein  
a carrier clock of an insulating coupler for receiving  
10 a modem signal is reproduced and used from a clock for  
a DC loop control signal path.

13. A modem device for modulating and  
demodulating a signal between application control  
means and a line, wherein said device has a line side  
15 circuit for inputting and outputting a signal between  
said line and a line connected to said line, a DSP for  
modulating or demodulating an I/O signal, an analog-  
digital interface between said line side circuit and  
said DSP, and an insulating coupler for separating  
20 said application control means and said line and a  
control signal is changed to an error correction code  
and then a signal is transmitted via said insulating  
coupler.

14. A system comprising application control means  
25 and a modem device for modulating and demodulating a

signal between said application control means and a line, wherein said modem device has an insulating coupler for separating said application control means and said line by a capacitive insulating barrier and  
5 at least said capacitive insulating barrier is formed on an SOI substrate.

15. An integrated circuit used in a modem device for modulating and demodulating a signal between application control means and a line, wherein a line  
10 side circuit for inputting and outputting a signal between said line and a line connected to said line and a capacitive insulating barrier which is connected to said line side circuit and insulates and separates between said line and said application control means  
15 are formed on the same SOI substrate.

16. An integrated circuit used in a modem device for modulating and demodulating a signal between application control means and a line, wherein an analog-digital interface and a capacitive insulating  
20 barrier which is connected to said analog-digital interface and insulates and separates between said line and said application control means are formed on the same SOI substrate.

17. A capacitive insulating barrier wherein a  
25 trench reaching a buried insulating layer is formed in

an SOI substrate, and an insulating band is formed by filling said trench with an insulator, and a capacity is formed by enclosing a silicon area on said SOI substrate by said insulating band.

5           18. A capacitive insulating barrier according to Claim 17, wherein a series capacity is formed by a multiple-insulating band.

10           19. A capacitive insulating barrier according to Claim 17, wherein a multiple inter-wiring-layer film is formed on the surface of said SOI substrate.

15           20. An insulating coupler wherein a capacitive insulating barrier that a trench reaching a buried insulating layer is formed, and an insulating band is formed by filling said trench with an insulator, and a capacity is formed by enclosing a silicon area on an SOI wafer by said insulating band, an input circuit, and an output circuit are formed on said SOI wafer, and these are enclosed by said insulating band into areas, and said areas are mutually insulated, and  
20           between said input circuit and one electrode of said insulating barrier and between the other electrode of said capacitive insulating barrier and said output circuit are wired.

25           21. An insulating coupler according to Claim 20, wherein said input circuit area and said output

circuit area are arranged with said insulating barrier between on said SOI substrate.

22. An insulating coupler according to Claim 20, wherein said area forming said insulating coupler is enclosed by said insulating band.

23. An insulating coupler according to Claim 20, wherein the inside of said circuit area is separated into a circuit area directly in contact with the power supply and an area directly in contact with the grounding terminal by said insulating band.

24. An insulating coupler according to Claim 20, wherein said coupler has a plurality of capacitive insulating barriers and the intermediate area of said plurality of insulating barriers is grounded.

25. An insulating coupler according to Claim 20, wherein a multiple-insulating trench is arranged in the outermost diameter zone on a chip.

26. An insulating coupler according to Claim 20, wherein a protection circuit having a non-linear device is arranged between said insulating barrier and said input circuit and output circuit.

27. An insulating coupler according to Claim 20, wherein said input circuit or said output circuit is a CMOS circuit and the area of said CMOS circuit is separated into a PMOS area and an NMOS area by said



insulating band.

28. An insulating coupler according to Claim 20,  
wherein said input circuit area, said output circuit  
area, and said capacitive insulating barrier are  
5 enclosed by insulating bands and the multiplexing rate  
of insulating bands of said circuit areas is higher at  
least one level than the multiplexing rate of  
insulating bands of said capacitive insulating barrier.

29. An insulating coupler comprising an input  
10 circuit, an output circuit, and a capacitive  
insulating barrier for insulating and separating said  
input circuit and said output circuit, wherein at  
least said capacitive insulating barrier is formed on  
an SOI substrate.

15 30. An insulating coupler wherein at least an  
input circuit, an output circuit, and a capacitive  
insulating barrier for insulating and separating said  
input circuit and said output circuit are integrated  
on the same semiconductor substrate and a pre-  
20 amplifier is arranged before a detection circuit for  
detecting an output signal of said capacitive  
insulating barrier.

31. An insulating coupler wherein a capacitive  
insulating barrier that a trench reaching a buried  
25 insulating layer is formed, and an insulating band is

formed by filling said trench with an insulator, and a capacity is formed by enclosing a silicon area on an SOI wafer by said insulating band, an input circuit, and an output circuit are formed on said SOI wafer and  
5 insulating bands for insulating and separating the area of said capacitive insulating barrier, the area of said input circuit, and the area of said output circuit have T-shaped or Y-shaped contact portions.

32. An insulating coupler wherein a first circuit  
10 area which is the primary side and a second circuit area which is the secondary side which are mutually insulated and separated are formed on the same semiconductor substrate and said coupler has a differential amplifier circuit for inputting a first  
15 pulse signal which is a digital signal and outputting a second paired pulse signal which is a complementary signal in said first circuit area, insulation and separation means having a paired capacitor for electrically separating said second paired pulse  
20 signal and connecting it from the primary side to the secondary side on said semiconductor substrate, a pair of differential means for generating a third paired pulse signal having a differential waveform corresponding to the transition time of said second  
25 paired pulse signal by connection from the primary

side in said second circuit area, and pulse  
demodulation means for using a third paired pulse  
signal as an input signal and reproducing said first  
pulse signal which is a digital signal from the edge  
5 timing of said paired differential signal obtained by  
said differential means in said second circuit area.

33. An insulating coupler according to Claim 32,  
wherein said differential means comprises a resistor  
device installed between the primary terminal of said  
10 insulation and separation means and the high potential  
power supply on the secondary side and the stationary  
level is the high potential power level.

34. An insulating coupler according to Claim 33,  
wherein the logical threshold value at the output  
15 stage of said first differential amplifier circuit for  
inputting said first pulse signal and outputting said  
paired pulse signal which is a complementary signal is  
on a level lower than  $1/2$  of the supply voltage at  
said output stage.

20 35. An insulating coupler according to Claim 32,  
wherein said differential amplifier circuit and said  
pulse demodulation means comprise CMOS.

36. An insulating coupler according to Claim 32,  
wherein the first stage of said pulse demodulation  
25 means comprises a pair of differential circuits.

37. An insulating coupler comprising a capacitive area having a band-shaped area in which a trench reaching a buried insulating layer is filled with an insulator as a dielectric, an input circuit area including a capacity drive circuit, and an output circuit area including a via-capacity signal detection circuit on an SOI wafer, wherein the substrate potential of said SOI wafer is a floating potential.

38. A monolithic insulating coupler comprising a capacitive area having a band-shaped area in which a trench reaching a buried insulating layer is filled with an insulator as a dielectric, an input circuit area including a capacity drive circuit, and an output circuit area including a via-capacity signal detection circuit on an SOI wafer, wherein the substrate potential of said SOI wafer is a floating potential and an external capacitor is connected between said substrate and the power supply or ground.

39. An AFE integrated circuit wherein an AFE (analog front end) circuit which is an analog-digital interface and an insulating coupler having a capacitive insulating barrier for insulating and separating between the analog I/O circuit and the digital I/O circuit of said AFE circuit are formed on the same SOI substrate.

40. An AFE integrated circuit according to Claim 39, wherein the AD conversion circuit and DA conversion circuit of said AFE circuit are of an oversample system and said insulating coupler is  
5 inserted between the oversample AD circuit and the AD digital signal processing circuit and between the oversample DA circuit and the DA digital signal processing circuit.

41. An AFE integrated circuit according to Claim  
10 39, wherein an insulating coupler for timing synchronization is arranged between said analog I/O side circuit and said digital I/O side circuit.

42. An AFE integrated circuit according to Claim 40, wherein a delay or advance of the ADC sample  
15 timing caused by the modem signal process is notified to said AFE circuit as a minute change of the oversample timing clock frequency and said AFE circuit generates an internal timing by PLL(phase locked loop)-synchronizing the internal clock with it.

20 43. An AFE integrated circuit comprising an AFE (analog front end) circuit which is an analog-digital interface and an insulating coupler having a capacitive insulating barrier for insulating and separating between the analog I/O circuit and the  
25 digital I/O circuit of said AFE circuit, wherein a set

of register and insulating coupler respectively installed on said analog I/O circuit side and said digital I/O circuit side are set as control register means.

5           44. An AFE integrated circuit comprising an AFE (analog front end) circuit which is an analog-digital interface and an insulating coupler having a capacitive insulating barrier for insulating and separating between the analog I/O circuit and the  
10       digital I/O circuit of said AFE circuit, wherein a set of register and monolithic insulating coupler respectively installed on said analog I/O circuit side and said digital I/O circuit side are set as general purpose I/O means.

15           45. A modem device comprising DAA means, AFE (analog front end) means, modulation and demodulation means, transmission control means, and insulation means between a line and application control means, wherein said insulation means is an insulating coupler  
20       having a capacitive insulating barrier.

          46. A modem device comprising DAA means, AFE (analog front end) means, interface means, and insulation means between a line and application control means, wherein said insulation means is an  
25       insulating coupler having a capacitive insulating

barrier.

47. A modem device according to Claim 45 or 46,  
wherein said AFE means contains said modulation and  
demodulation means.

5 48. A modem device according to Claim 45 or 46,  
wherein said AFE means contains a plurality of  
insulating couplers and said modulation and  
demodulation means.

10 49. A modem device according to Claim 45 or 46,  
wherein as serial bus connection means between the  
modem portion and said application control means,  
interface means comprising serial bus connection  
hardware and serial bus transmission software is used  
for both said modem portion and said application  
15 control means.

50. A system comprising a modem device according  
to Claim 45 or 46 and application control means  
connected to said modem device.

20 51. A communication device comprising at least a  
plurality of stations including network control and  
application circuit means, transceiver means,  
insulating means between said network control means,  
said application circuit means, and said transceiver  
means, and power regulator means and network means for  
25 connecting between each station, wherein said

insulation means is an insulating coupler having a capacitive insulating barrier.

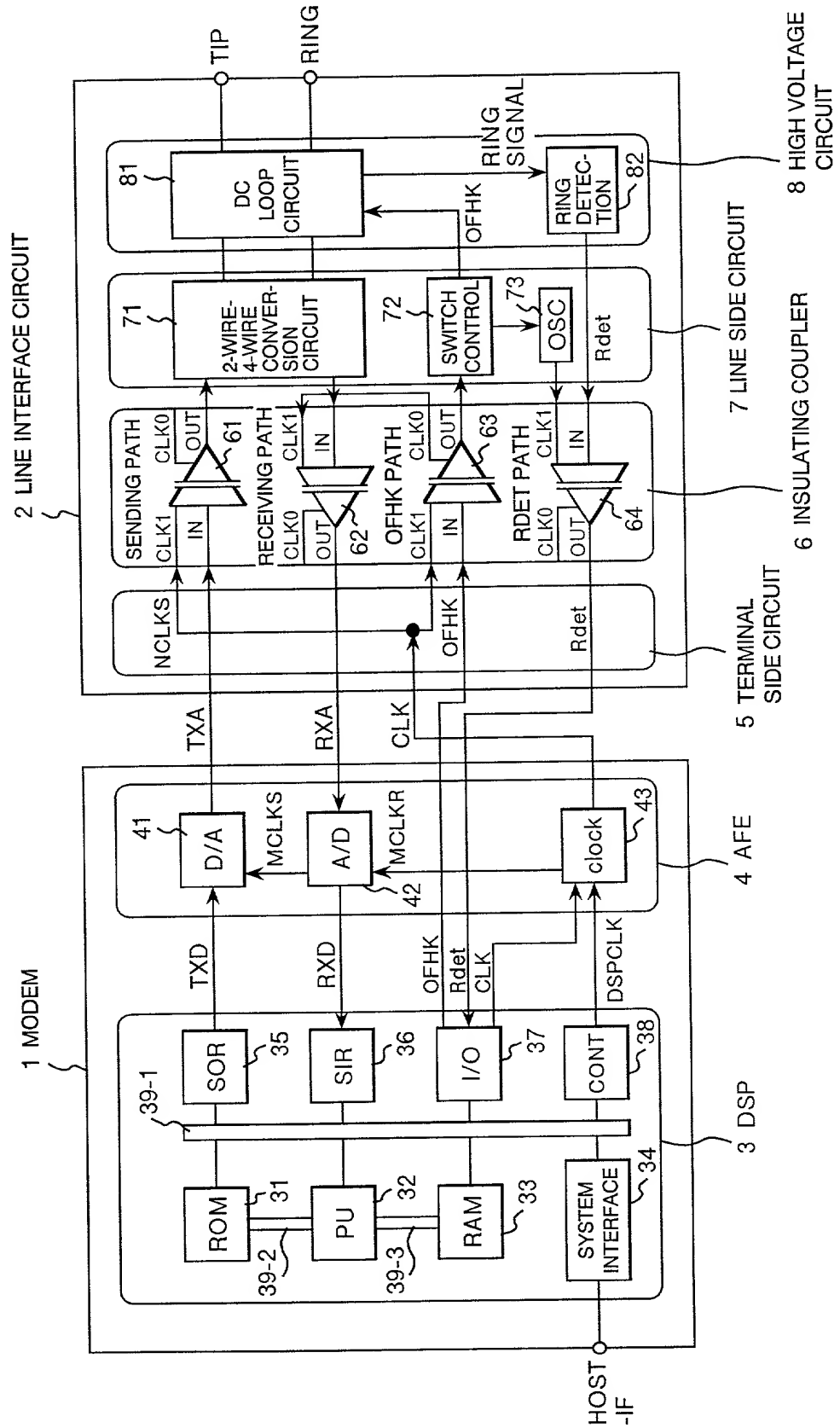
52. A communication device according to Claim 51,  
wherein said insulating coupler and said network  
5 control and application circuit means or said  
transceiver means or both of them are integrated to  
one semiconductor chip.



ABSTRACT

When an insulating coupler having a capacitive  
insulating barrier is formed on an SOI substrate and  
the timings of the DSP, AFE, and insulating coupler  
5 are synchronized using the DSP operation clock, the  
line interface circuit is made monolithic. By doing  
this, a miniature and economical modem device can be  
realized.

FIG. 1



OPERATION TIMING CHART OF THE MODEM DEVICE SHOWN IN FIG. 1

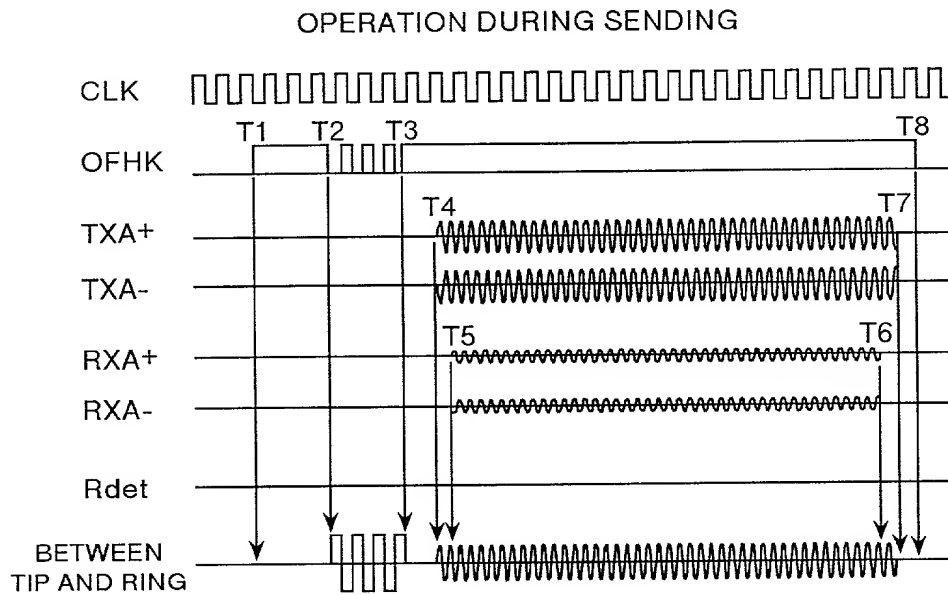
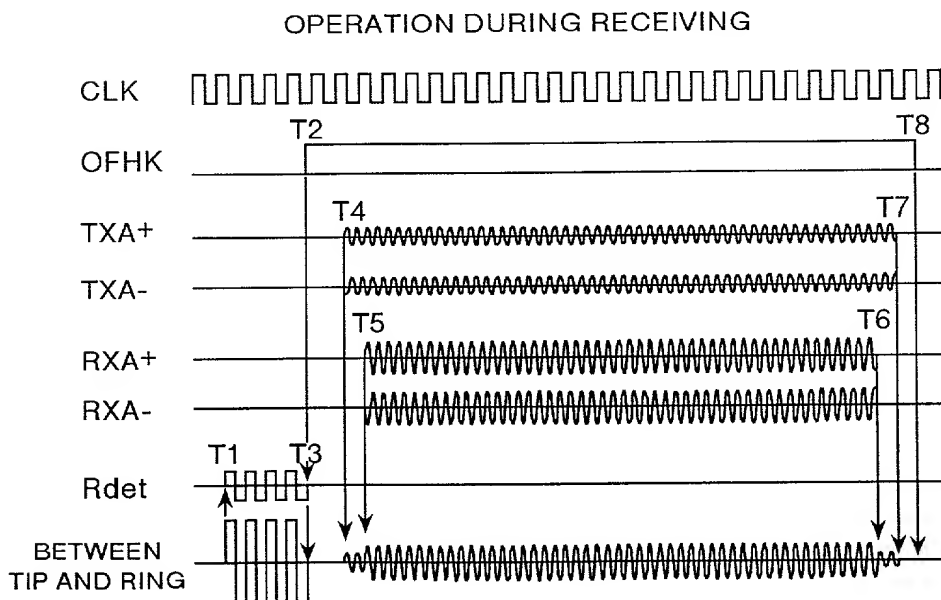
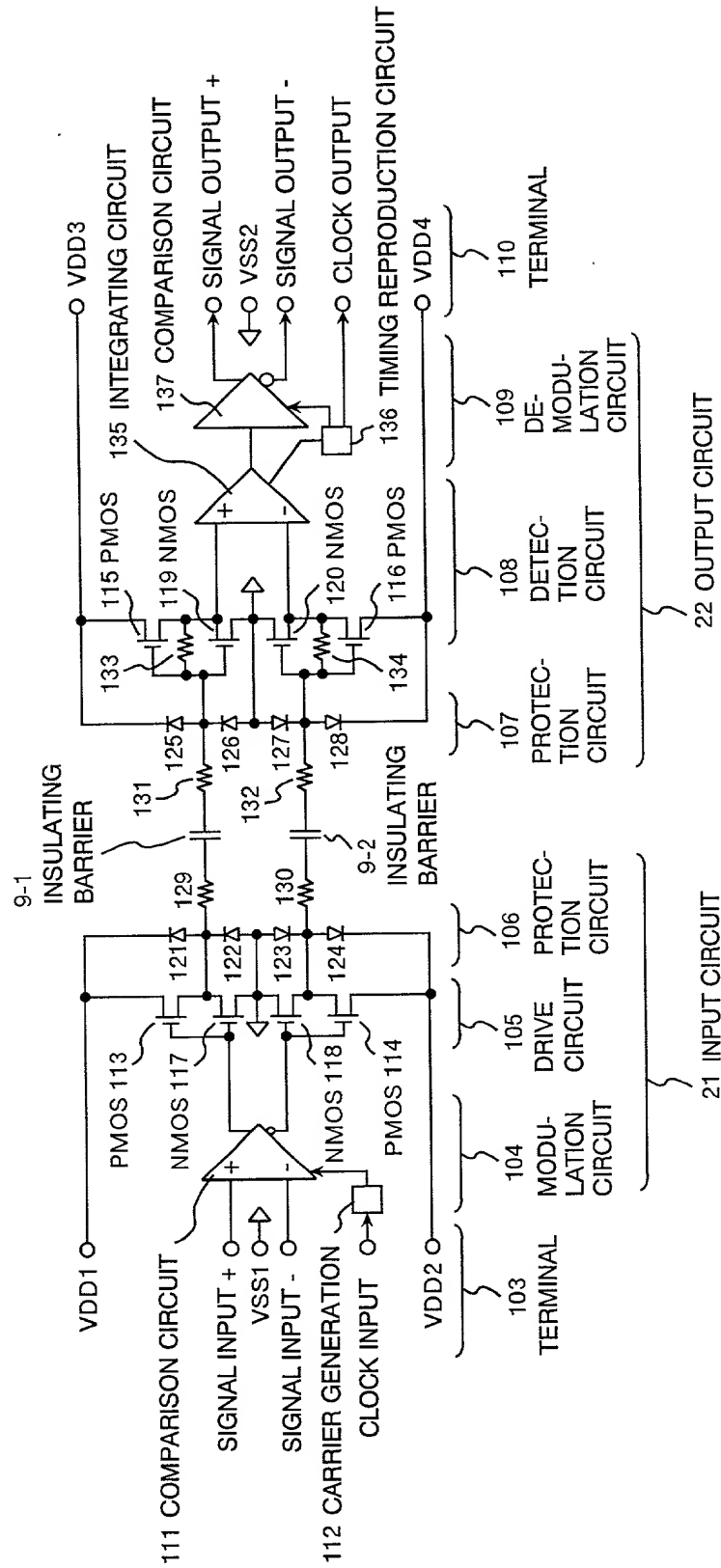
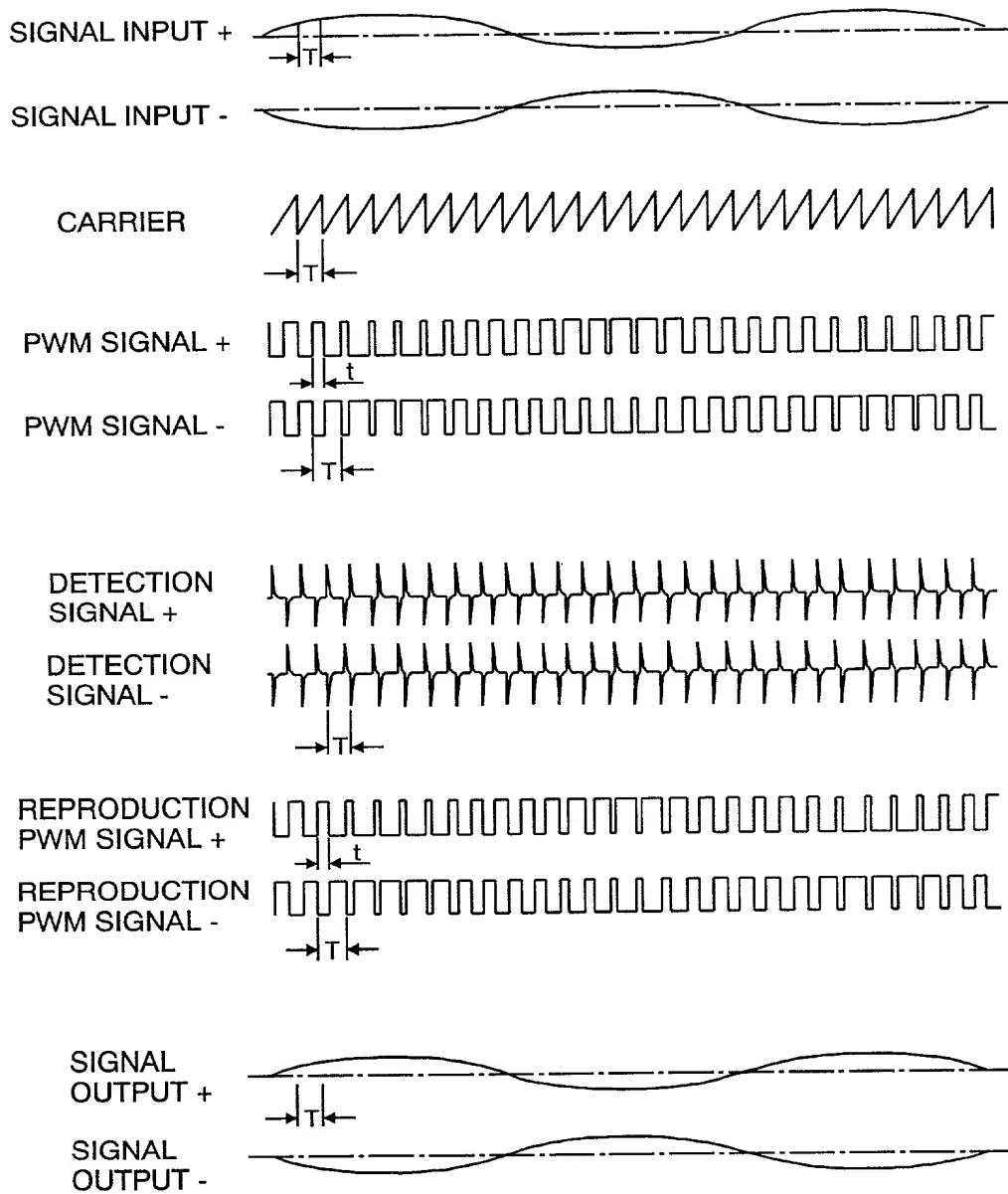
**FIG. 2a****FIG. 2b**

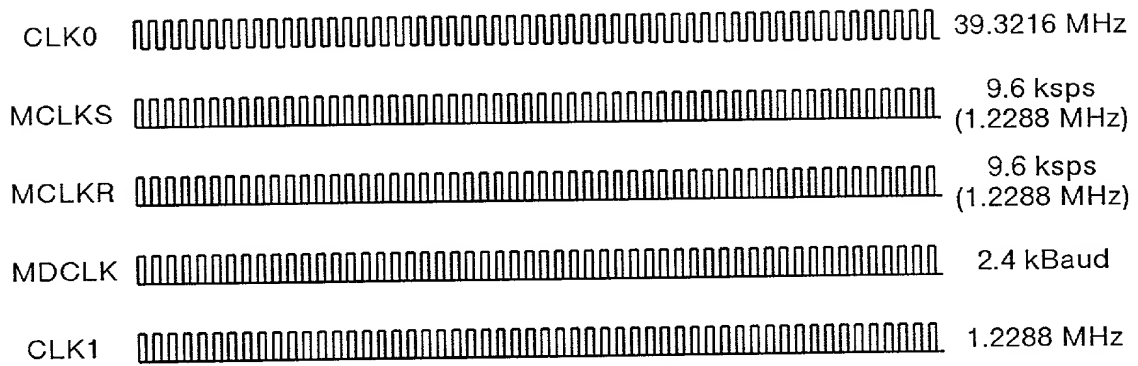
FIG. 3



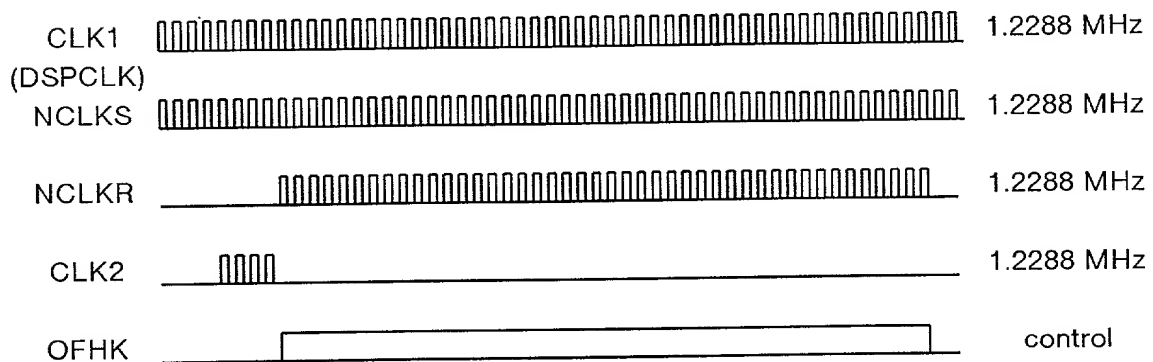
**FIG. 4**

**FIG. 5a**

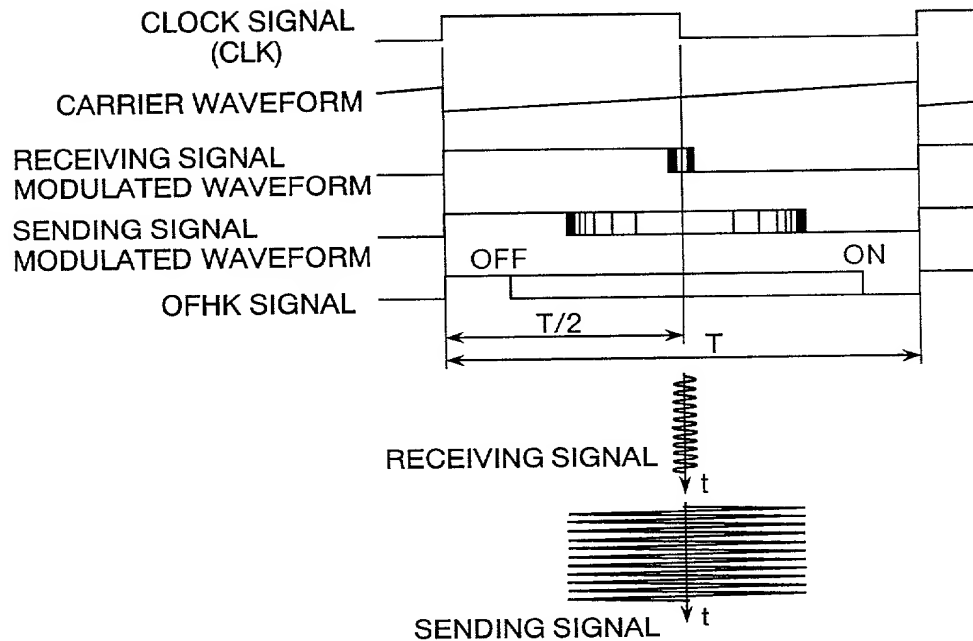
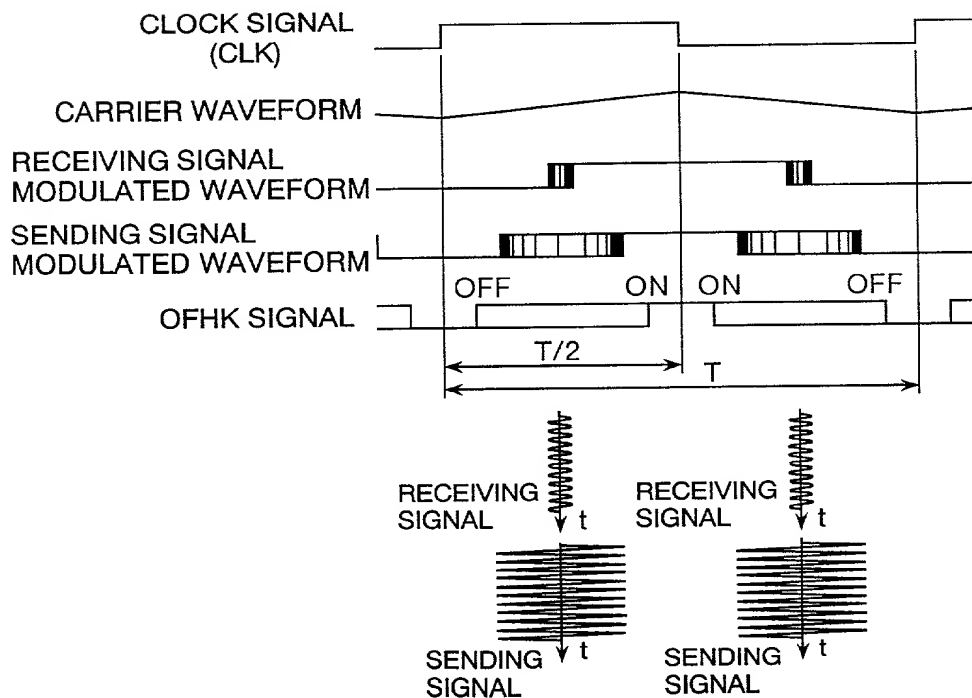
## MODEM SIGNAL PROCESSING PORTION

**FIG. 5b**

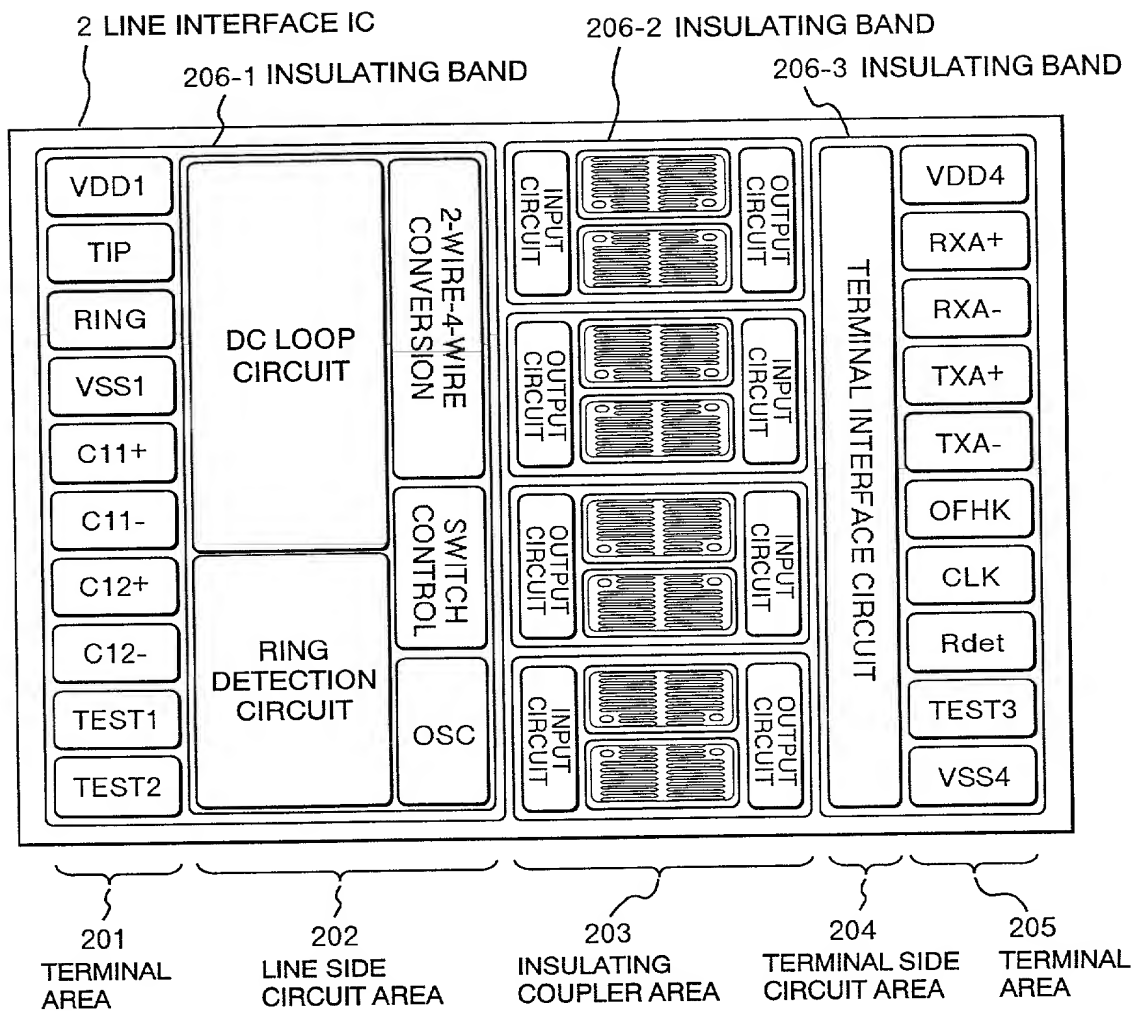
## LINE INTERFACE PORTION



6/19

**FIG. 6a****PWM TIMING OF SAW TOOTH CARRIER****FIG. 6b****PWM TIMING OF SYMMETRICAL CARRIER**

7/19

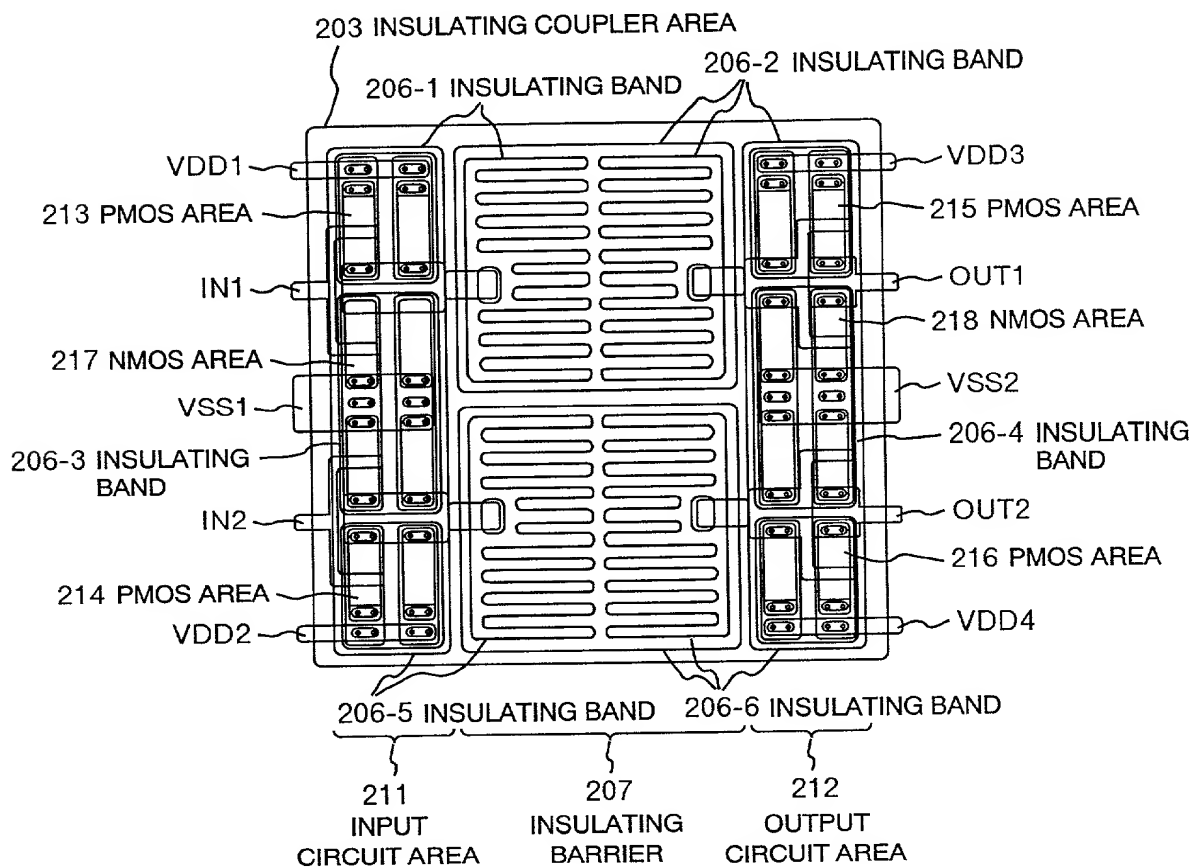
**FIG. 7**



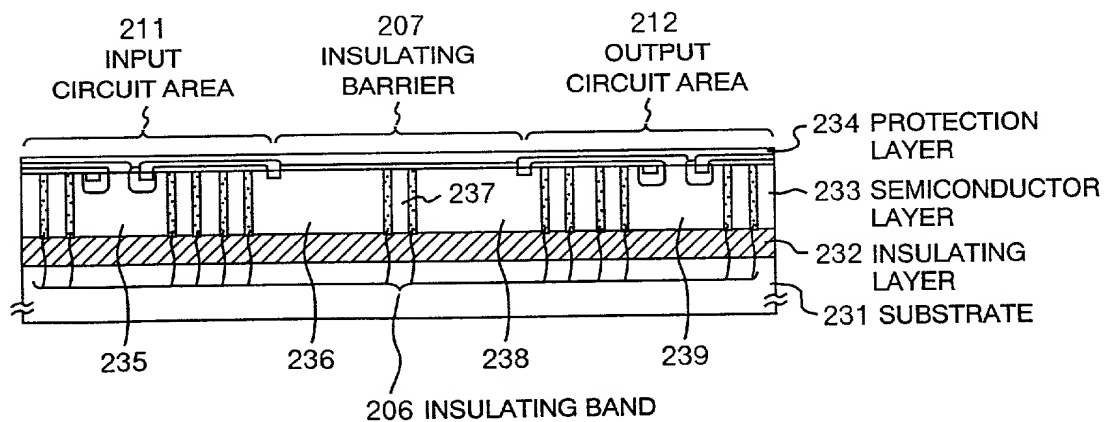
8/19

**FIG. 8a**

## PLAN VIEW OF INSULATING COUPLER

**FIG. 8b**

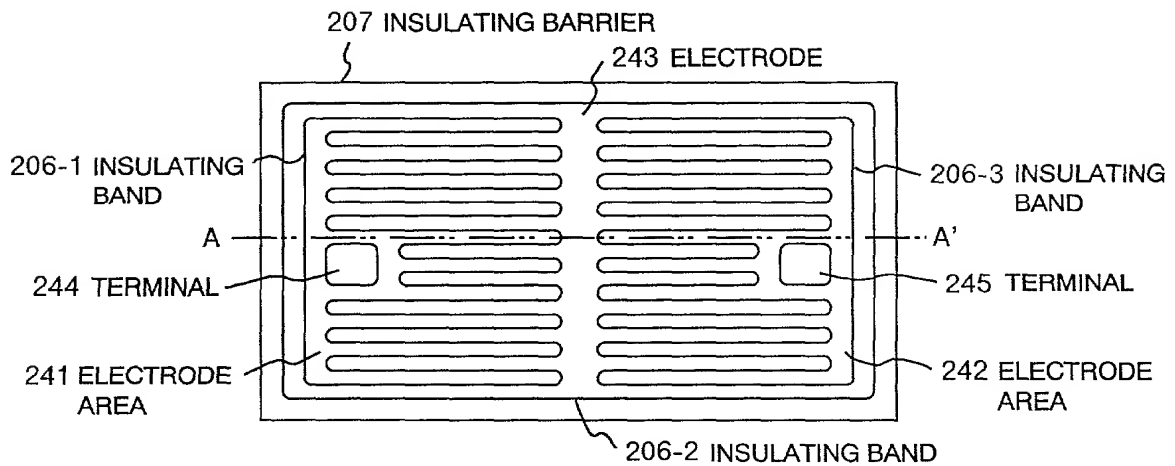
## CROSS SECTIONAL VIEW OF INSULATING COUPLER



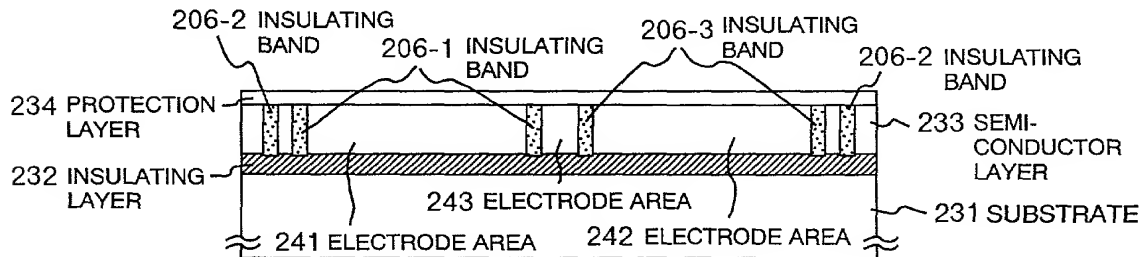
9/19

**FIG. 9a**

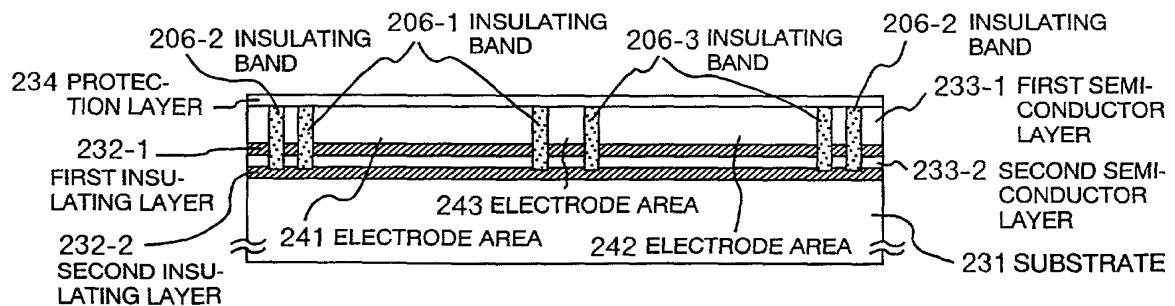
PLAN VIEW

**FIG. 9b**

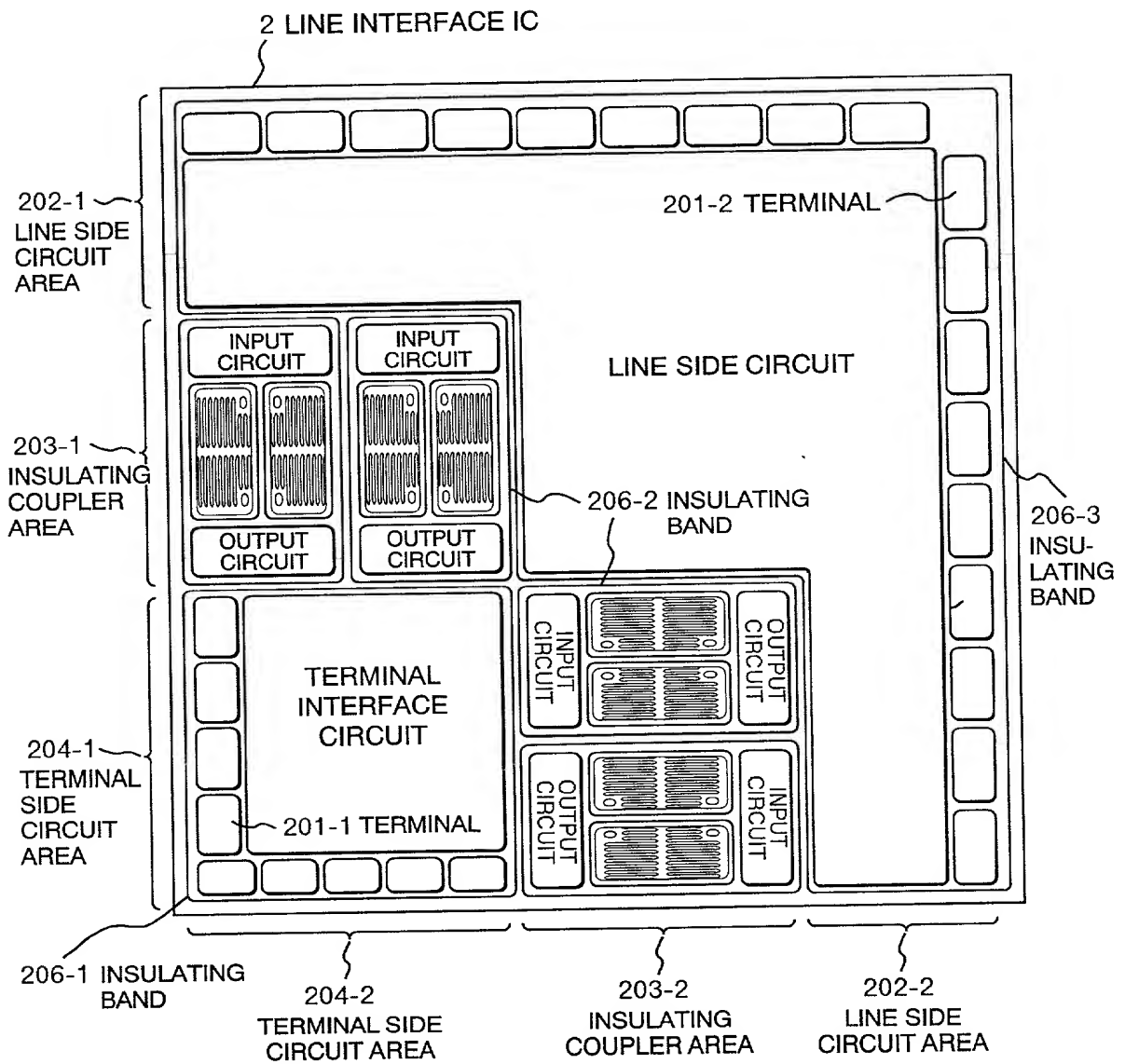
A-A' CROSS SECTIONAL VIEW OF ONE-INNER LAYER TYPE

**FIG. 9c**

A-A' CROSS SECTIONAL VIEW OF TWO-INNER LAYER TYPE



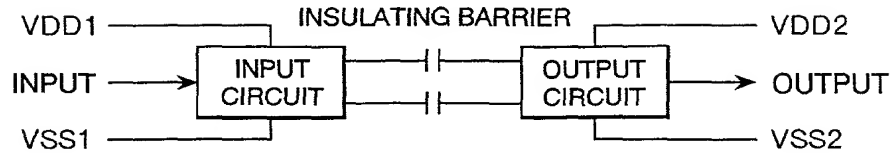
10/19

**FIG. 10**

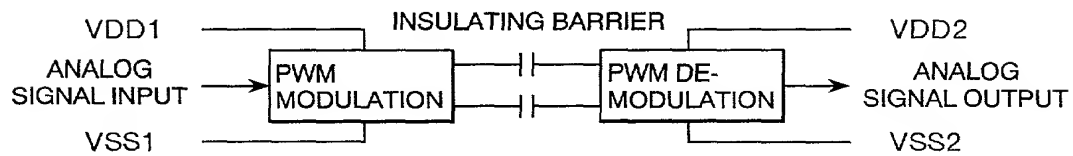
11/19

**FIG. 11a**

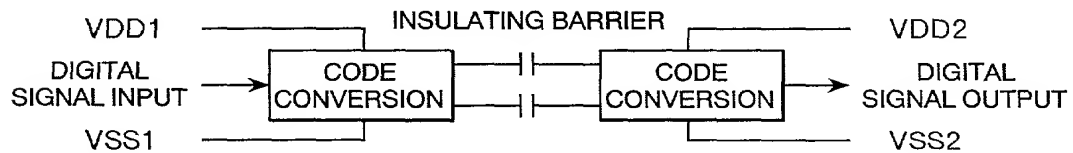
INSULATING COUPLER

**FIG. 11b**

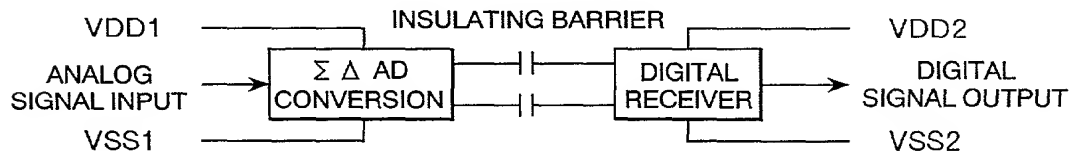
PWM TRANSMISSION SYSTEM

**FIG. 11c**

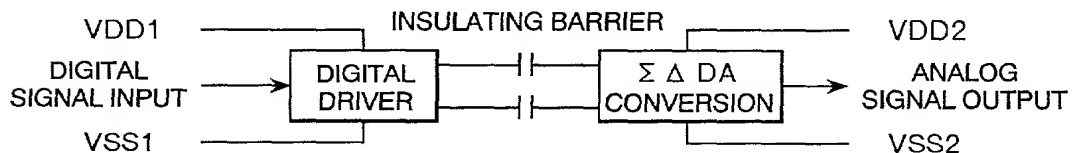
DIGITAL TRANSMISSION

**FIG. 11d**

AD CONVERSION

**FIG. 11e**

DA CONVERSION

**FIG. 11f**

DIGITAL TRANSMISSION

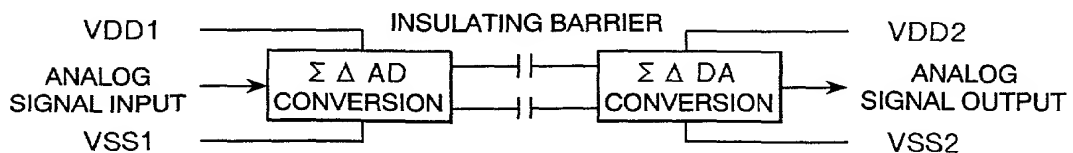
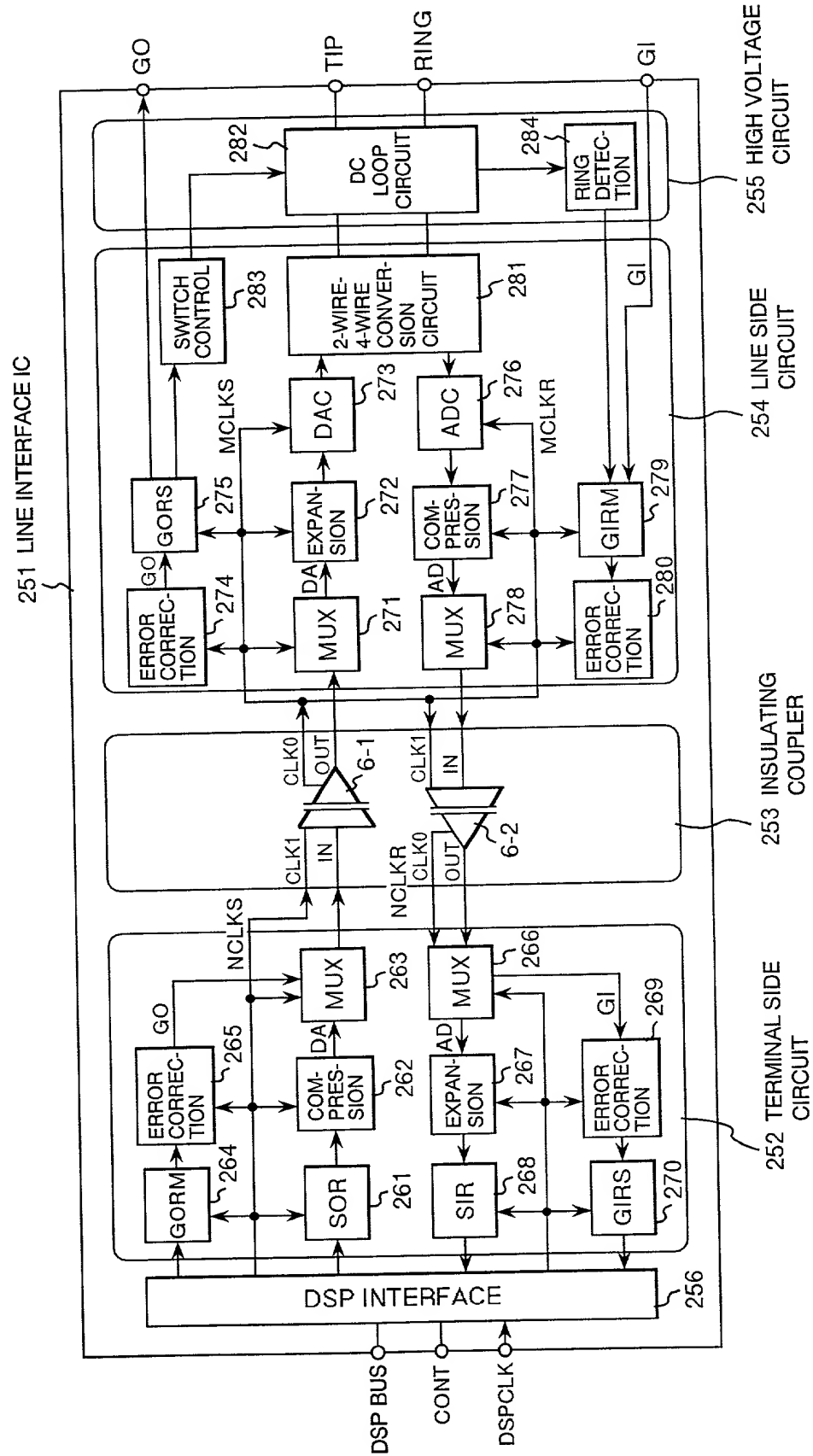


FIG. 12



13/19

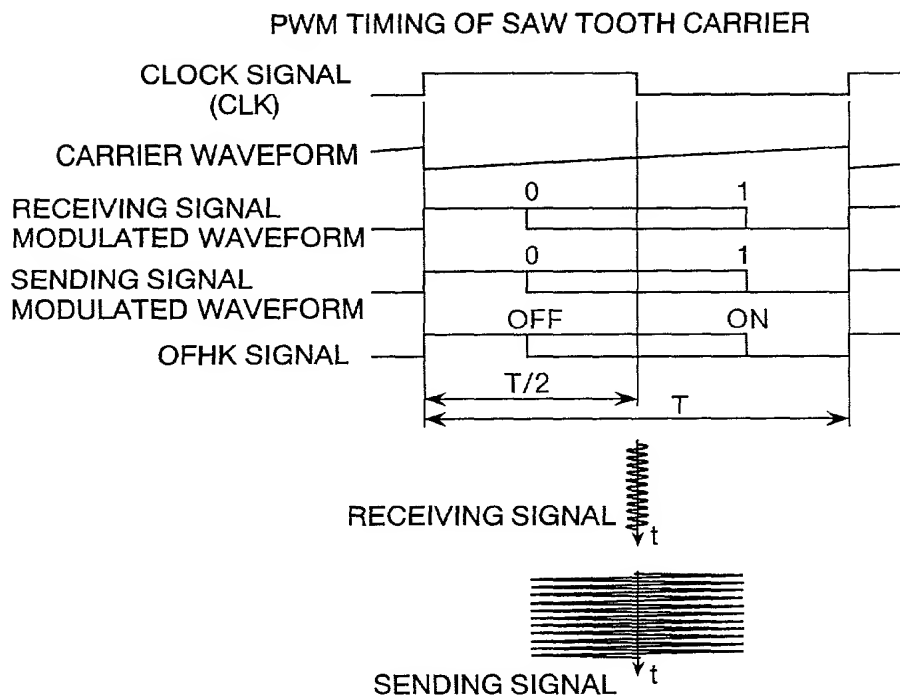
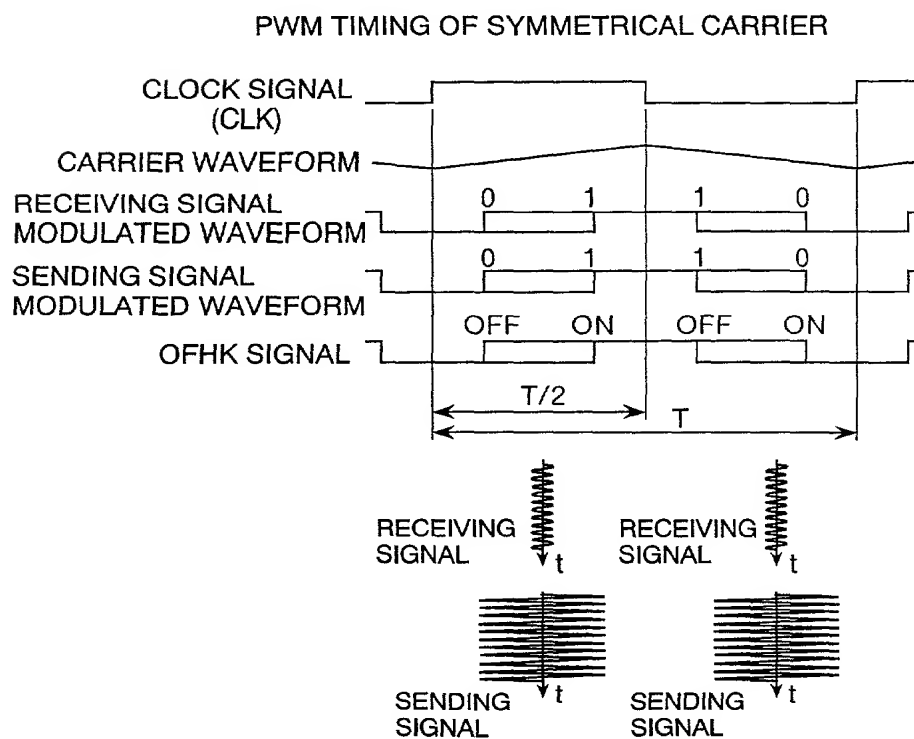
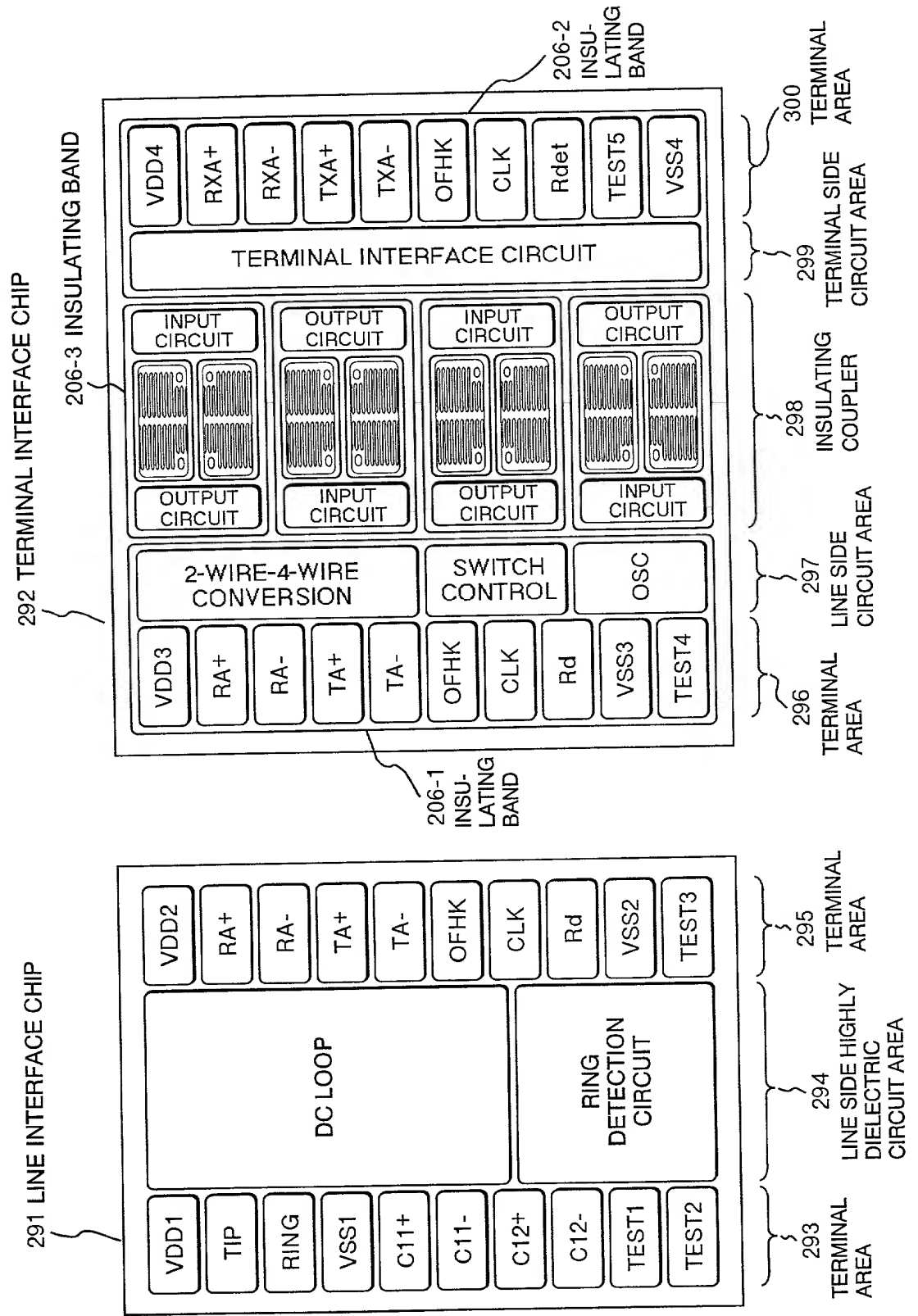
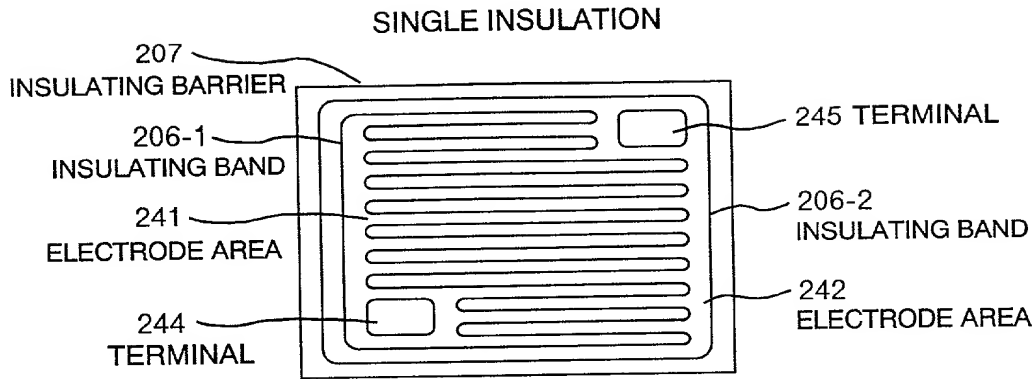
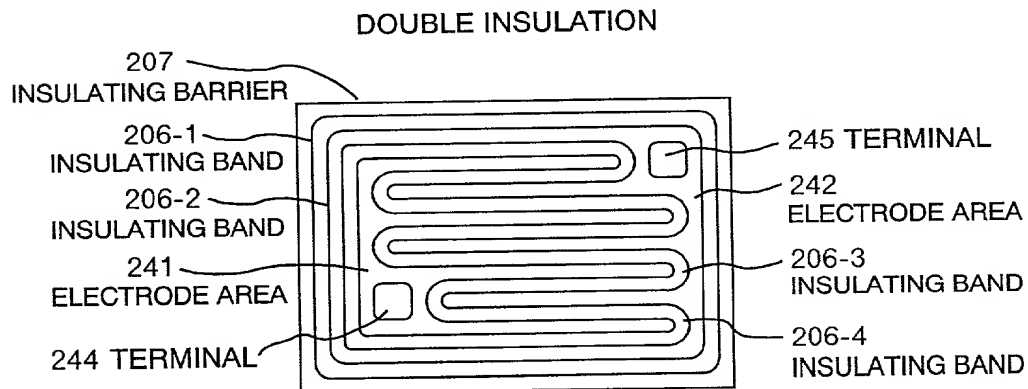
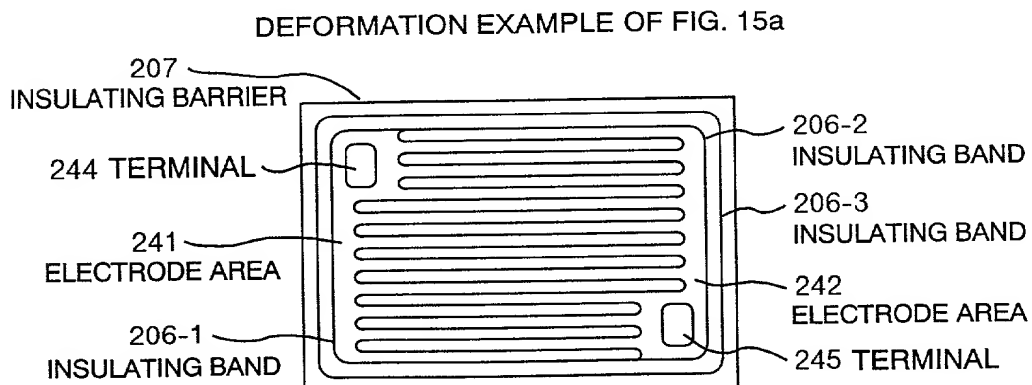
**FIG. 13a****FIG. 13b**

FIG. 14



**FIG. 15a****FIG. 15b****FIG. 15c**



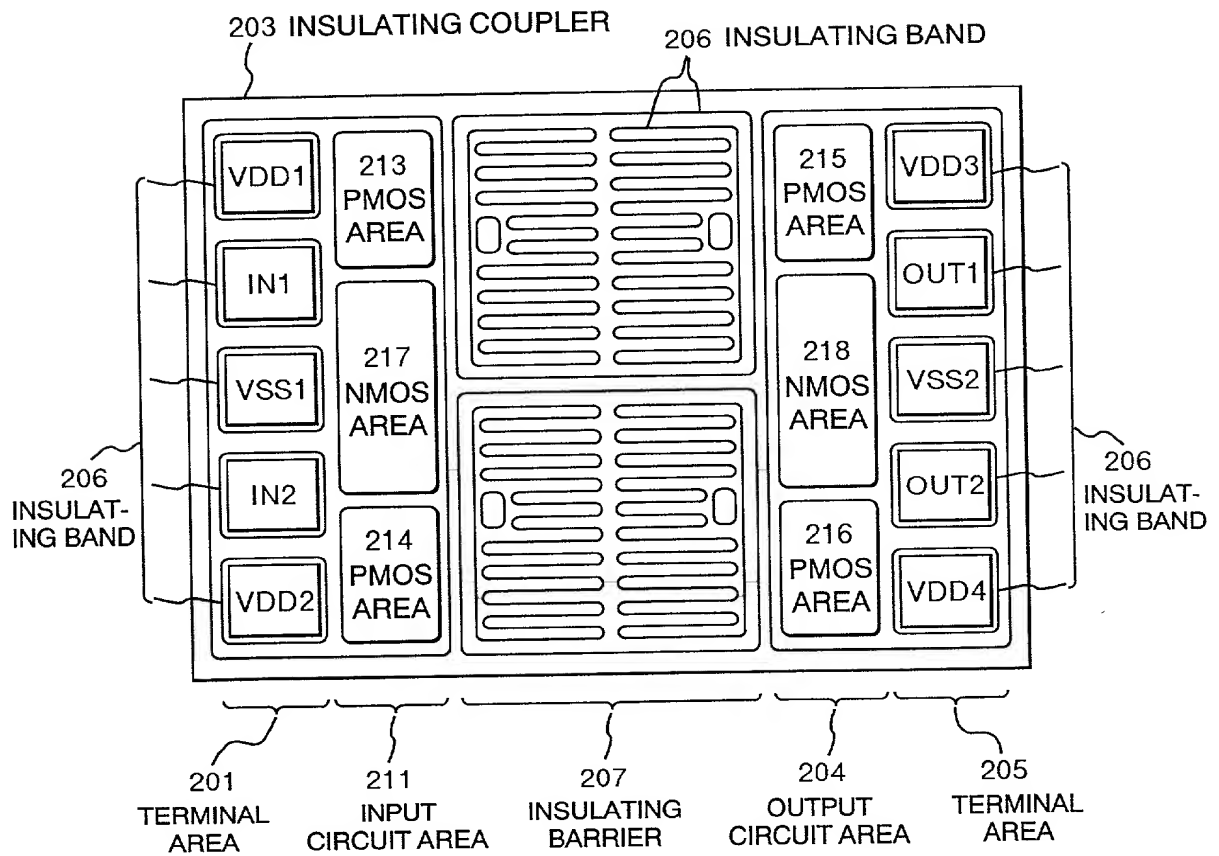
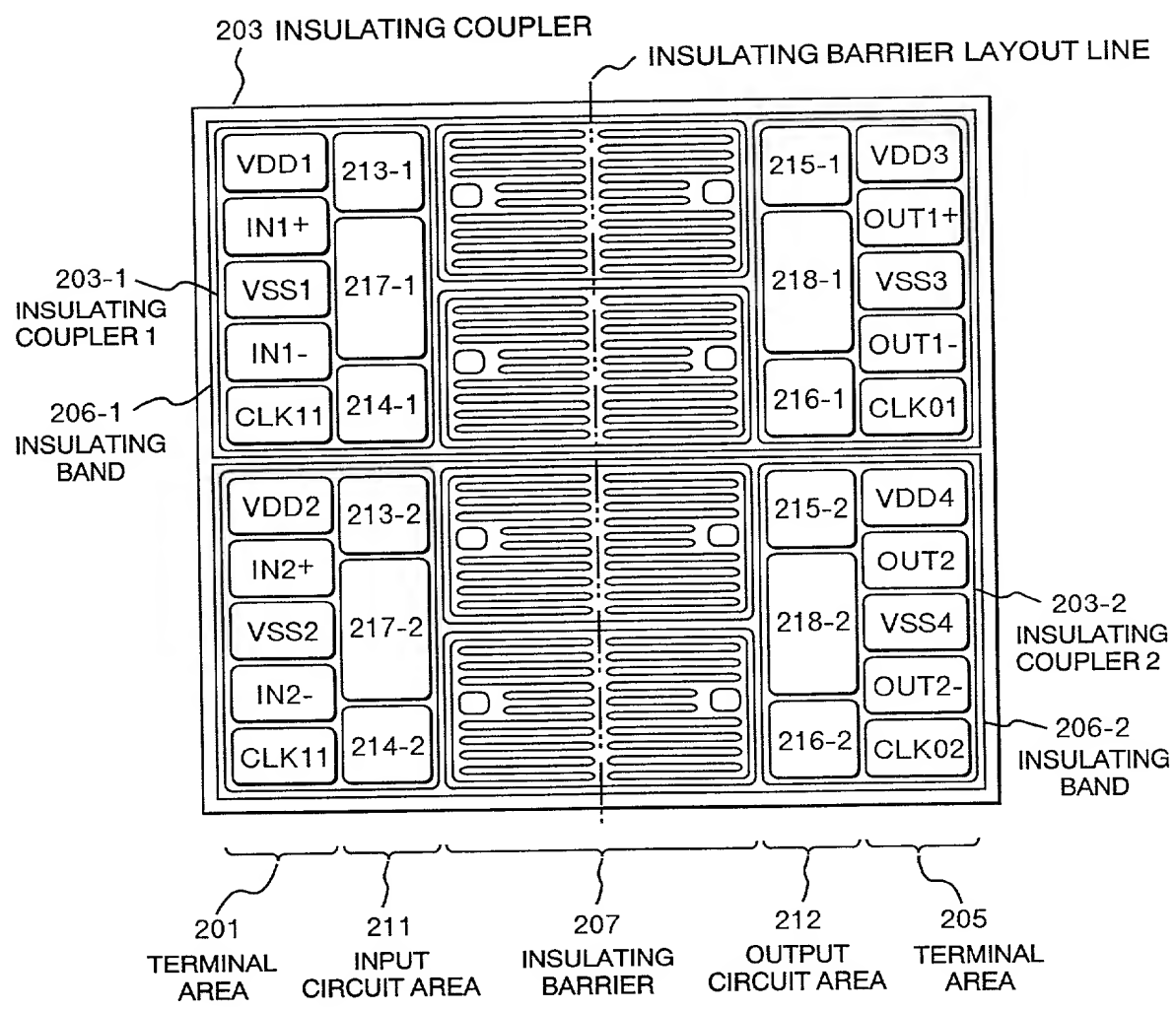
**FIG. 16**

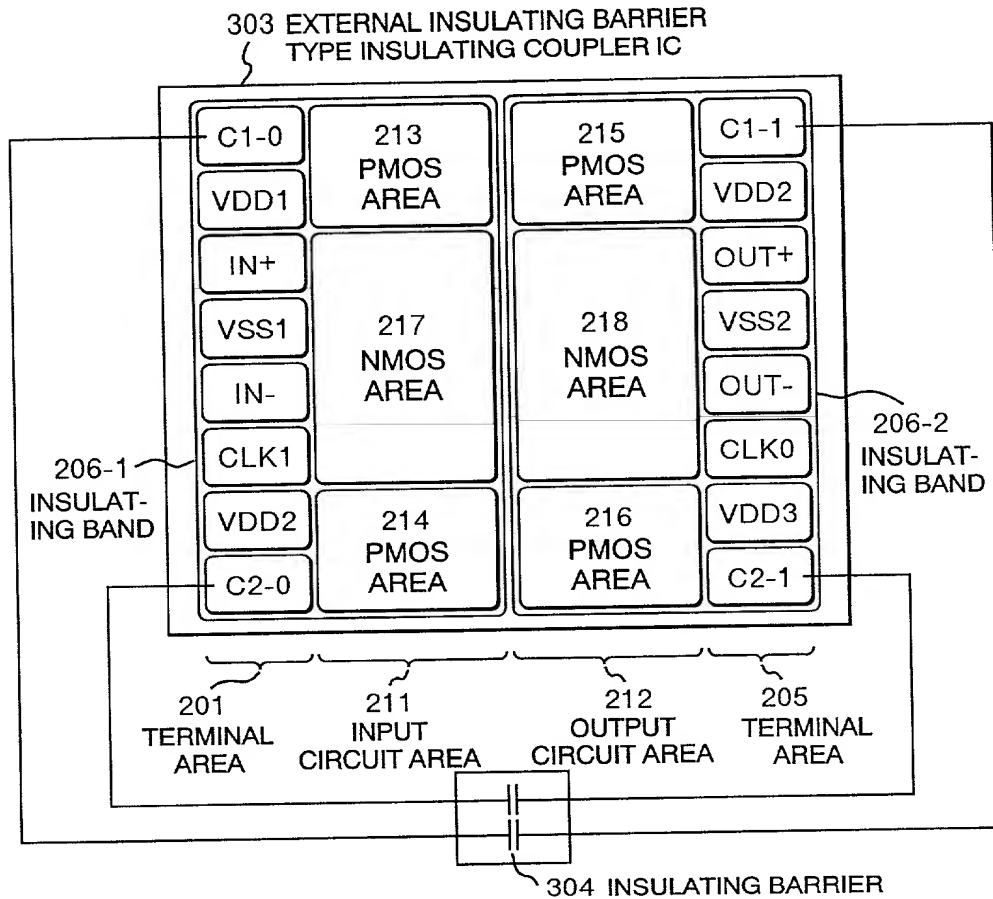
FIG. 17



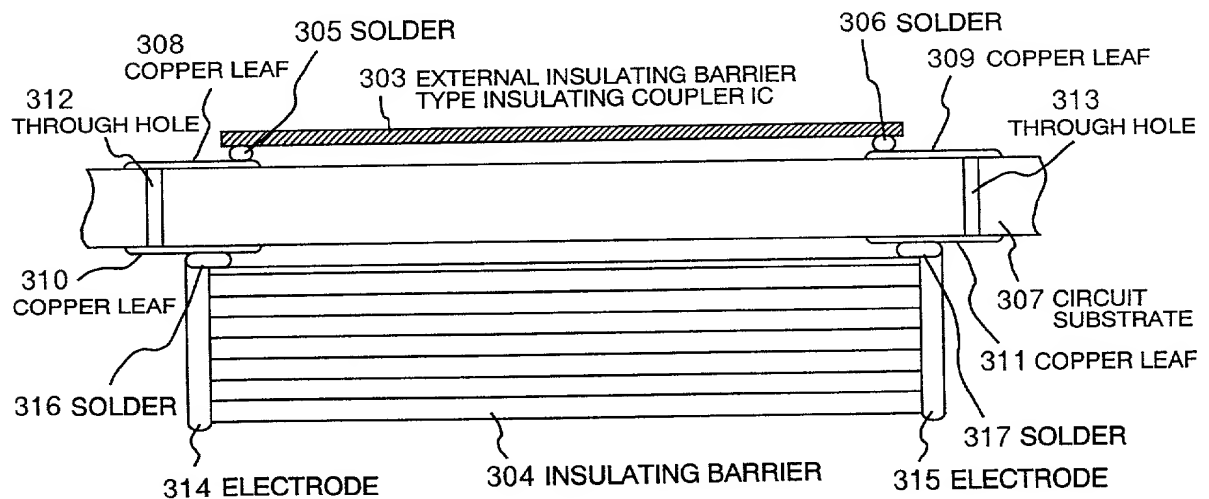
18/19

**FIG. 18a**

## OUTLINE OF CHIP LAYOUT

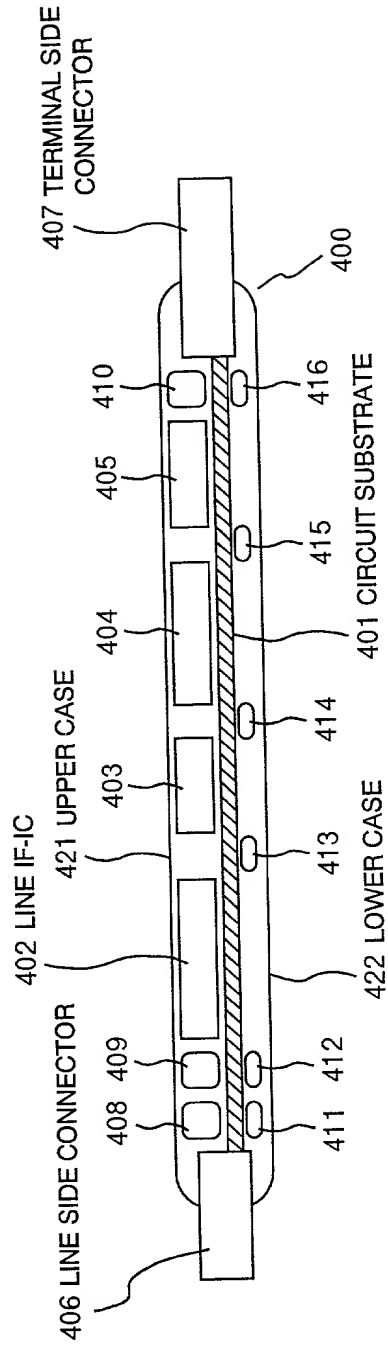
**FIG. 18b**

## CIRCUIT SUBSTRATE MOUNTING CROSS SECTIONAL VIEW



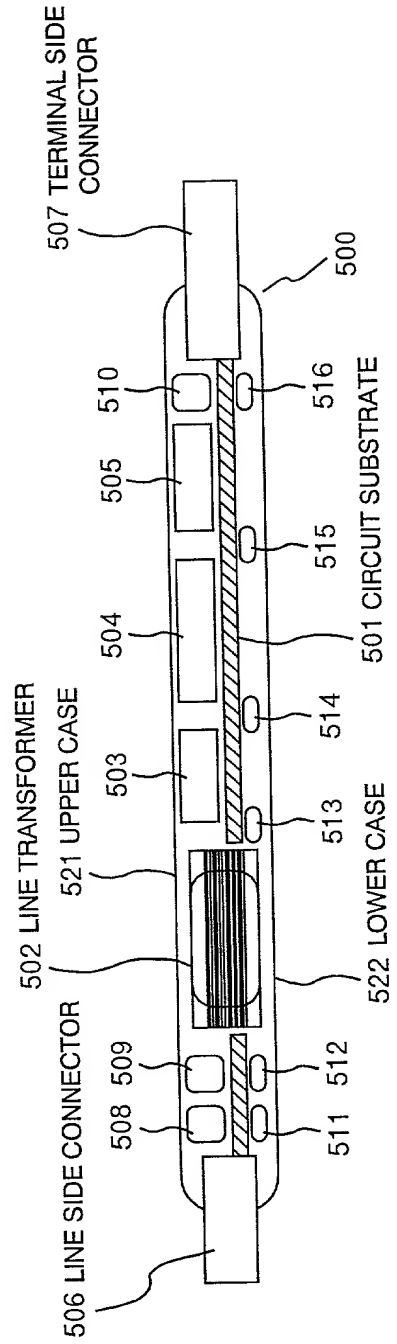
**FIG. 19a**

STRUCTURE OF AN EMBODIMENT OF THE PRESENT INVENTION



**FIG. 19b**

STRUCTURE OF A CONVENTIONAL MODEM DEVICE



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420 Rec'd PCI/PIO 30 SEP 1999

PTO/SB/122 (11-96)

Approved for use through 6/30/99. OMB 0651-0035

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Application Number

09/402148

Filing Date

September 30, 1999

First Named Inventor

Y. KOJIMA, ET AL

Group Art Unit

Examiner Name

Attorney Docket Number

520.37678X00

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## DECLARATION AND POWER OF ATTORNEY FILED WITH U.S. DESIGNATED OFFICE UNDER 35 U.S.C. 371(c)(4)

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name, I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

A MODEM DEVICE USING A CAPACITIVE INSULATING BARRIER, AND INSULATING  
COUPLER, AND AN INTEGRATED CIRCUIT USED IN THE MODEM DEVICE

the specification of which was filed as PCT International Application No. PCT/JP98/01431

filed March 30, 1998 and was amended on \_\_\_\_\_ (if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

## Prior Foreign Application(s)

## Priority Claimed

<u>9-079551</u> (Number)	<u>Japan</u> (Country)	<u>31/Mar./1997</u> (Day/Month/Year Filed)	<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> Yes	<input type="checkbox"/> No
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> Yes	<input type="checkbox"/> No
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> Yes	<input type="checkbox"/> No
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> Yes	<input type="checkbox"/> No
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> Yes	<input type="checkbox"/> No

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

_____ (Application Serial No.)	_____ (Filing Date)	_____ (Status: patented, pending, abandoned)
_____ (Application Serial No.)	_____ (Filing Date)	_____ (Status: patented, pending, abandoned)
_____ (Application Serial No.)	_____ (Filing Date)	_____ (Status: patented, pending, abandoned)
_____ (Application Serial No.)	_____ (Filing Date)	_____ (Status: patented, pending, abandoned)

I hereby appoint as principal attorneys; Donald R. Antonelli, Reg. No. 20,296; David T. Terry, Reg. No. 20,178; Melvin Kraus, Reg. No. 22,466; William I. Solomon, Reg. No. 28,565; Gregory E. Montone, Reg. No. 28,141; Ronald J. Shore, Reg. No. 28,577; Donald E. Stout, Reg. No. 26,422; Alan E. Schiavelli, Reg. No. 32,087; James N. Dresser, Reg. No. 22,973 and Carl I. Brundidge, Reg. No. 29,621 to prosecute and transact all business connected with this application and any related United States application and international applications. Please direct all communications to the following address:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Residence _____		Citizenship _____
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